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Technology in Education

Letter from the Editor

ROSELMINA INDRISANO, BOSTON UNIVERSITY

The theme of this issue, Technology in Education, calls to mind Webster's definition of transition: "a passage from one state, stage, subject, or place to another." Each article focuses on an aspect of the use of technology in the field of education and in the process of educating as we teach and learn in a time of transition.

The issue begins with a case study by Tisha Y. Lewis that is based on research for which she received the Promising Researcher Award from the National Council of Teachers of English in 2012. Researchers who study child development have provided increasing evidence that education begins and is nurtured in the home. Dr. Lewis's case study of an African American nine-year old and his mother invites us into their home where texting and instant messaging are the reasons for a son's explanation, "We txt 2 sty cnnectd." The author suggests that the insights derived from this work that was situated within the framework of New Literacies Studies and multimodality, offer "the potential to change the perceptions of literacy researchers regarding the dynamics of family structures" (p. 1).

The second article, written by Luciana C. de Oliveira and Larisa Olesova, is a report of a study of teachers and teacher candidates as they used asynchronous online discussions in an online course that focused on the language and literacy development of English Language Learners. The research was designed to investigate the major themes identified by the subjects as well as the ways these topics were discussed in the online approach. The findings suggest that the discussions affected the participants' levels of understanding regarding the literacy development of English Language Learners. Since these learners are part of the largest growing group of students in the United States, these insights, derived through the use of technology in higher education, will inform teacher educators, and also, school-based practitioners.

Patricia Moyer-Packenham and her colleagues focus on the second of the basic processes, mathematics, as they report on an aspect of their ongoing study of virtual manipulatives, this one conducted in the critical middle grades in elementary school. The results showed no significant differences in achievement between the use of physical and virtual manipulatives, a long-debated question. In addition, their study revealed that objective ability has the potential to predict fraction achievement, that virtual manipulatives use can be modulated by test question type, and that allocating different percentages of class time to the two types of manipultives has the potential to provide differential opportunities to learn.

Researchers at the University of Kansas and their colleagues are the authors of the final two articles. The first report by Diana L. Greer, Stephen Crutchfield, and Kari L. Woods focuses on a topic that has long been central to the work of the Research Center—learning disabilities. In the article in this issue, the ways computer-based and online learning environments can inform both cognitive theory and instructional design are described. Noting that learners who struggle and those with learning disabilities, "often exhibit unique cognitive processing and working memory characteristics that may not align with instructional design principles developed with typically developing learners" (p. 41), the authors begin with an explanation of two theories that inform their work and present empirically supported design principles based on these theories. They conclude with implications for computer-based and online learning environments.

In the final article, James D. Basham and his colleagues "examine the complex array of variables and implementation models that must be accounted for during the pivot from a purely brick-and-mortar educational system to one that makes use of both virtual and blended environments" (p. 51). Emphasizing instructional goals and design principles over the capabilities of technology, they suggest that educational leaders and researchers must assume a role in

> using technology to enhance the accessibility and usability of curricular materials to meet the needs of different types of learners, advancing the understanding and practices of in-service and pre-service teachers through preparation that focuses on online learning, and fostering collaboration between educational researchers and technology innovators and developers to build a research base that will inform K–12 online education. (p. 51)

The call of these authors and the insights revealed by the other researchers whose studies are reported in this issue are central to the work of our readers who are teachers, researchers, administrators, curriculum and materials designers, pre-service and in-service teacher educators, innovators, and families. As the insights in this issue suggest, in this time of transition for society as a whole, and education in particular, it is our shared scholarship and wisdom that will serve us best as we develop and use technology now and in the future to ensure the success of every generation of learners.

"We txt 2 sty cnnectd": An African American Mother and Son Communicate: Digital Literacies, Meaning-Making, and Activity Theory Systems

TISHA Y. LEWIS, GEORGIA STATE UNIVERSITY

I text because it is a way for me to be with my mom. (Gerard)

We text to stay connected . . . to spend time without us interfering in each other's space. (Larnee)

ABSTRACT

This research demonstrated how an African American mother and son communicated with each other via texting and instant messaging (IM) at home. Data from a 2007 larger ethnographic case study of a family's digital literacy practices were collected and analyzed. Situated within the framework of New Literacy Studies and multimodality, this research explored: a) how and why an African American mother and son communicated through texting and IM, b) how this family drew on multimodal meaning-making resources, and c) how texting and IM between these family members demonstrated the potential to change the perceptions of literacy researchers regarding the dynamics of family structures.

INTRODUCTION

This article focuses on the ways an African American mother and son communicated via digital literacies and how their use of texting and IM shaped their family's relationships. I define *digital literacies* as multiple and interactive practices, mediated by technological tools such as the computer, cell phones, and video games that involve reading, writing, language, and exchanging information in online environments (Lewis, 2009). Grounded in previous research on family literacies (Cairney & Ruge, 1998; Edwards, Pleasants, & Franklin, 1999; Heath, 1983; Rogers, 2002; Taylor, 1983; Taylor & Dorsey-Gaines, 1988) and the burgeoning study of digital literacies, this study is guided by the following more specific inquiries: a) How and why do an African American mother and son text and IM each other? b) How does this family draw on multimodal meaning-making resources? c) How might texting and IM between family members change the dynamics of family structures?

Engaging in digital literacy practices in the Ali household (all names are pseudonyms) required skill, creativity, and collaboration. Larnee Ali, a divorced African American mother of four sons, who was in her mid-30s, and Gerard, her nine-year-old son, relied on various forms of interaction with digital tools on a daily basis. Most of their digital literacy practices consisted of texting and IM, troubleshooting, creating blogs, and designing digital comic strips. Larnee and Gerard's words, quoted at the beginning of this article, suggest that connecting with digital tools was a source of bonding and spending quality time together. Their words also suggest the changing times and views of literacies in family literacy research. Larnee explained the affinity she shared with Gerard for digital literacies and their daily co-participation in digital activities. Their actions show the idiosyncratic ways that some families communicate in today's digital world. Hence, Larnee and Gerard determined and defined the meaningful, cultural, and authentic literacy practices in their lives.

My shared and distant experiences with Larnee suggested that a family's digital literacy practices vary based on the need and desire for these tools, but our experiences also allow us the ability to connect and engage with digital literacies as key components of life. As documented in this study, families still use literacy for a wide variety of purposes, audiences, and situations (Cairney & Ruge, 1998; Compton-Lilly, 2003; Edwards, 2004; Edwards, 2010; Edwards, Pleasants, & Franklin, 1999; Heath, 1983; Rogers, 2002, 2003; Taylor, 1983; Taylor & Dorsey-Gaines, 1988), but today's families' literacy skills and practices are "multiple and travel between sites" (Pahl & Rowsell, 2006, p. 9). They are constantly evolving, shifting, and weaving families' identities, values, languages, and experiences through the digital and multimodal. These data, collected from a larger ethnographic case study, represent an African American mother and son's digital literacy practices (Lewis, 2009, 2010a, 2010b, 2011) and highlight how texting and IM between Larnee and Gerard introduced innovative communication practices that extended family dynamics and structures.

THEORETICAL PERSPECTIVES AND RELEVANT LITERATURE

New Literacy Studies and Multimodality

This study was framed within the notion that literacy extends beyond language, is not the same in all contexts, and is a collection of social practices (Barton & Hamilton, 1998; Barton, Hamilton, & Ivanic, 2000; Gee, 1996; Heath, 1983; Street, 1995, 2003). Researchers who conduct "new literacy studies" (NLS) offer a body of scholarship across a range of social, cultural, historical, and political situations, contexts, and practices. The NLS perspective suggests that literacy is more than simply reading and writing; literacy is a way of acting, knowing, valuing, believing, learning, and using multiple tools and technologies (Gee, 2010; Street, 2003). The process is inseparable from the practices and is connected to other tools. For instance, typing on a computer is a literacy event

situated in time and space; however, going online to check and respond to emails, to peruse, and to post responses on social networking sites (i.e., Facebook and Twitter) opens up other spaces and identities that infuse social practices in different domains or spaces in life (Pahl & Rowsell, 2011).

Being literate in most families today means engaging in digital literacy practices that involve various multimodal modes and expressions that include linguistic as well as gestural and meaning-making processes (Jewitt & Kress, 2003; Norton-Meier, 2005). Using these multimodal connections, researchers are able to understand more completely how video games, cell phones, the Internet, digital books, and texting and instant messaging, for instance, involve semiotic systems (signs and symbols) (Kress & van Leeuwen, 2001).

Multimodality offers opportunities to explore how individuals communicate using a range of different modes (visual, gestural, linguistic, auditory, and spatial) to make and create meaning. According to Kalantzis, Cope, and Cloonan (2010), "meaning making in the digital communications environment of the 21st century is being transformed" (p. 62). Activities involve multiple modes—sometimes simultaneously—and all are important for communication and meaning making. For example, we use our digital phones (aside from talking) for sending pictures, sending texts, recording video, and posting images—all in record time. We use these forms of multimodal expressions to respond to others and communicate our ideas.

In addition, our meanings are based on our understanding of how to make sense of each practice within the social environment (Kress, 2003). It is important to clarify how activities are embedded (and interpreted) within conventional ideas about what is an "appropriate" social practice. For instance, a parent sending a text to a child setting a curfew may not be effective, but texting "I love you" to a child displays a wonderful term of endearment. In addition, when someone sends a text, the "typical" response is to reply with a text, rather than calling the individual. These examples signify that there are unwritten rules that guide our use of the tools that are part of social and multimodal practices.

In a twenty-first-century digital world where individuals compete for accessibility and socialization, vis-à-vis digital tools, research has emerged to indicate how individuals interact with digital literacies. A number of researchers have explored media-related literacy practices in school and community contexts. These studies examine topics such as digital literacies (Bruce, 2002; Hagood, 2000; Joaquin, 2010), instant messaging (Jacobs, 2006; Lewis & Fabos, 2005), multimodalities that individuals use on a daily basis in online communities (Rowsell & Burke, 2009; Vasudevan, DeJaynes, & Schmier, 2010), and pop culture and adolescents' use of online literacies (Alvermann, 2002, 2008, 2010; Cammack, 2002; Chandler-Olcott & Mahar, 2003; Kirkland, 2009; Mahar, 2002). However, there is still a limited amount of research that focuses on family literacy and digital literacy practices, specifically, how they contribute to the increasing technological demands of the home and the larger world, and influence how families talk, think, value, and identify themselves when engaging in the use of technologies.

Family Literacy Studies

Considerable work on family literacy practices has recognized how these practices are situated in the home (Cairney & Ruge, 1998; Edwards, 2004; Edwards, et al., 1999; Heath, 1983; Rogers, 2002; Taylor, 1983; Taylor & Dorsey-Gaines, 1988). Taylor (1983) originated the concept of *family literacy* in her dissertation study, even though she did not use the specific term. She examined a family's "literacy styles and values" (p. 20) within the context of a study of parents and children. Subsequent studies identified the discursive and literacy patterns of families, the dichotomies between homes and schools, and how families from marginalized socioeconomic spaces were perceived (Compton-Lilly, 2003; Lareau, 1989; McCarthey, 1997; Morrow, 1995a; 1995b; Purcell-Gates, 1995; Rogers, 2003). Later studies associated family literacy with the ways individuals "learn and use literacy in their homes and community lives" (Crawford & Zygouris-Coe, 2006, p. 261). Earlier and later researchers also examined the significance of diversity and culture in family literacy (Auerbach, 1989, 1995; Cairney 1997, Cairney & Ruge, 1998; Compton-Lilly, Rogers, & Lewis, 2012; Gadsden, 1995, 2004). The work of these family literacy scholars has had profound influence on the ways we identify the nature, function, and significance of family literacy practices in the home.

Family literacy research has only recently begun to address the significance of digital literacies. In *The Smith Family's 85th Birthday Special Report Series* (2008), it is stated:

> [A]t the family and community level, the goal is to increase *connectedness* in both the physical and virtual sense, (e.g., connectedness between family members, between families and communities, and between individuals and information resources). The key focus here was on the engagement of disadvantaged and marginalized groups in order that they may participate more fully both from a social and economic perspective. (p. 9) (emphasis in the original)

Within this focus, some studies have contributed to our understanding of the ways families have used various forms of digital tools to interact with others to enhance literacy learning among its members, from young children to adults.

Snyder, Angus, and Sutherland-Smith (2002) examined the use of information and communication technologies (ICT) in low-income homes and documented how families' lifestyles, values, and norms varied. The particular focus was on students' learning. In addition, Marsh's (2006, 2011) and Marsh and Thompson's (2001) research with younger and older children with regard to popular culture and media texts, out-of-school techno-literacies, and literacy practices in a virtual world revealed the multiple ways families interacted with digital literacies to maintain an "online interaction order" (Marsh, 2011, p. 101). Other studies have focused on how families drew on multimodal modes to participate

in the transformation of meaning-making processes, and the effect on young children's metacognitive development (Stein & Slonimsky, 2006; Wolfe & Flewitt, 2010). Norton-Meier (2005) examined her role as a learner, troubleshooter, and strategizer to handle problems that arose when playing video games with her husband and adolescent children. These studies provide evidence of the ways new digital tools create meaning and are embedded in the lives of individuals and families.

Fortunately, some research highlights families' digital literacy practices through diverse lens. Ba, Tally, and Tsikalas (2002) examined nine low-income and ten middle-income African American and Latino families and their use of home computing practices that influenced and shaped their social, technological, and school environments. Hawisher, Selfe, Moraski, and Pearson (2004) explored how an African American woman and a European American woman's acquisition and development of technologic competence, through literacy narratives, influenced their literate lives.

While the cited research helped shape my thinking about this topic, I found little research on how digital literacy practices, such as texting and IM, and the growing dependence upon multimodal communication systems, affect a family's use of such literacies. To fill this gap, I initiated this investigation of how an African American mother and son's digital literacy practice of texting and IM helped them to make sense of their lives. The findings demonstrate how family communication through digital tools enhanced learning and provided new insights regarding family literacy in today's digital society. Since a primary focus was on the use and practice of texting and IM, I discuss how this digital practice became a form of popular culture in our society.

Texting and IMing As Popular Culture Literacies

Within the past decade, the use of texting and IM has increased, turning this practice into a popular trend in mobile communication to include components of reading and writing, including vocabulary development, particularly among adolescents and older family members. As a result, texting and IM are important tools to explore in literacy research (Drouin, 2011; Drouin & Davis, 2009; Jacobs 2006, 2008; Lenhart, Ling, Campbell, & Purdell, 2010; Lewis & Fabos, 2005; Reardon, 2008). According to the Pew Research Center's Internet & American Life Project (2010), 87% of individuals use text messaging on regular basis, and these numbers continue to increase. Texting also has the potential of extending the dynamics of family structures. While texting can take away the face-to-face communication in the home, over 98% of parents stated that the primary reasons their child has a cell phone are safety and the convenience of reaching the child at a moment's notice (Pew Research Center's Internet & American Life Project, 2010).

In addition to texting, research shows that IM has also become a rapidly growing activity (Jacobs, 2006, 2008; Lewis & Fabos, 2005). Instant messaging entails real-time, private exchanges of typed text between two individuals via the Internet. However, some teachers and parents have misinterpreted IM because they think that this practice is inconsistent with the new literacies (Jacobs, 2008). Vygotsky (1978) and Rogoff (1990, 2003) have noted that individuals learn effectively when they are engaged in practices within a community where they are valued and appreciated. Research has examined how adolescents' engagement in IM helped shape their social identities (Lewis & Fabos, 2005). Jacobs (2006) discovered the ways adolescents' use of IM and its meanings applied to literacy learning between IM and formal writing in-and out-of-school literacies. In discussing IM and its relationship to literacy, Lewis and Fabos (2005) stated, "IM motivates young people to engage in decoding, encoding, interpretation, and analysis, among other literacy processes, and yet very little empirical work has focused on this form of digital literacy" (p. 473). Among those who have studied this topic is Jacobs (2008) who examined the benefit of IM as a way for adolescents to "build the skills, attributes, and achievements that position them for participation in a fast capitalist information economy" (p. 204)—for example, the rapid intensity of purchasing products for consumption. Jacobs' work demonstrated how an adolescent female became proficient in writing at school because IM was a part of her range of literacy practices.

While teens still choose to communicate via email for school and personal matters, when sending casual written messages quickly to friends and family members, "online instant messaging is clearly the mode of choice for today's online teens" (Lenhart, Madden, & Hitlen, 2005, p. ii). Texting and IM are two of the most frequent communication activities among adolescents/teens and family members. This finding suggests that it is important to investigate ways to "reconceptualize literacy in digital mediated times" (Cohen & Cowen, 2010, p. 50). Therefore, I argue that texting and IM between a mother and her son must be considered of paramount importance to understanding the dynamics of communication using these tools. In the section below, I explain my research methods.

METHODOLOGY

Participation Selection and Stories

As a reading specialist at an after-school program, for over two years, I taught three of Larnee Ali's sons. I identified the Ali family for study after Gerard and I began to converse about his fascination with print and digital comic strips. In addition, Larnee was the sole initiator of digital literacy practices in the home. Based on the criteria of family access to, and participation with, digital tools on a daily basis, and my rapport with the family, I chose the Alis because of the ways in which digital literacy practices were embedded in their lives. An in-depth understanding of digital literacies within this family provided a unique and complex portrait of family literacy practices. In the sections below, I introduce Larnee and Gerard and tell their personal stories.

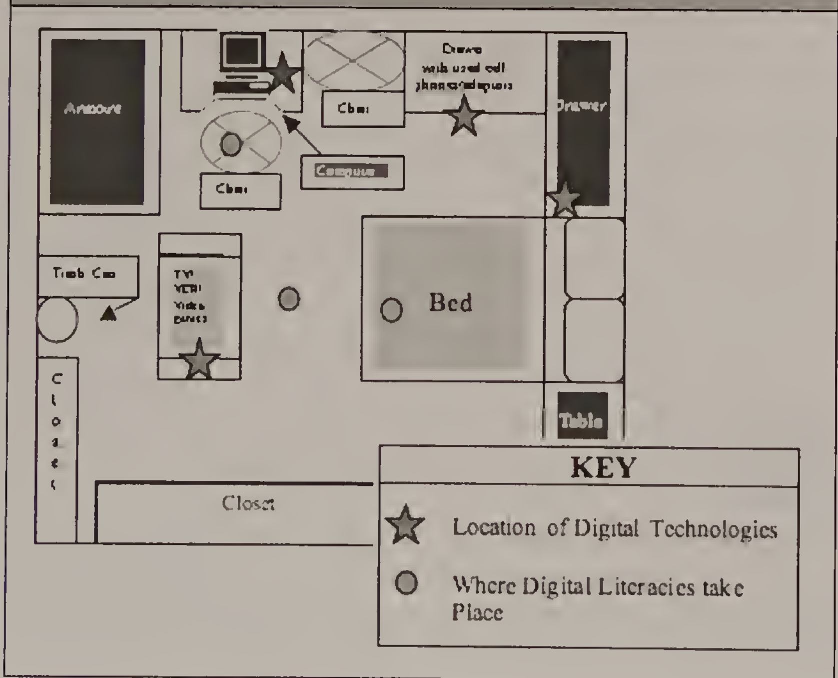
Larnee's story. Larnee is one of 19 siblings, a divorced mother of four, in her mid-30s. Born with epidermolysis bullosa (EB) (a rare skin disease), Larnee is physically limited in obtaining and holding a job for an extended amount of time. She is a recipient of Supplemental

Security Income (SSI) via the Social Security Administration (SSA), and has attempted to obtain her G.E.D. In addition, she is a survivor of childhood physical and sexual abuse. Her attraction to technological tools, as a child, provided an escape from this abuse and the lack of parental involvement in the home. Television, phones, and pagers became her "family," unlike her natural family. Her childhood room became an oasis of creativity, peace, and contentment because of the presence of technological tools. Despite her arduous past, she has now become what I call an *initiator of digital tools*, one who takes digital tools and introduces them into a practice—to start a chain reaction. Within this role, she frequently connected and interacted with her sons around digital literacies which defined for her a sense of awareness, agency, and apprenticeship to identify how digital literacies helped her make sense of her life (Lewis, 2009, 2010a, 2010b, 2011).

Gerard's story. Gerard is a middle son in a family of four boys. He is nine years old and attends a public school where he is an A to B student. Gerard completed standard academic and psychological testing in 2005 that diagnosed him with attention deficit hyperactivity disorder (ADHD). He took medication that addressed his inattentive behavior of not focusing or concentrating on tasks at home and school. Gerard and his brothers were picked up from school every day to go to the after-school program and stayed there until it closed at 7p.m. His love for digital literacies grew in his own home. He spent hours engaging in digital literacy practices, such as designing a digital comic strip, playing The Sims 2 videogame with his cousin, or blogging and texting/IM with his mother.

Context. The primary site of the data collection was Larnee's bedroom where the only computer in the home was located. Used for game playing, computer/Internet use, communication, and enjoyment, Larnee's bedroom was layered with artifacts that made sense to her. Figure 1 displays a blueprint of the room as a context that the family understood to be a place that was walked through, lived in, and experienced, and where learning and interaction took place over time (Comber, Thompson, & Wells, 2001; Pahl & Rowsell, 2010).

Figure 1. Blueprint of Larnee's Bedroom



Data Collection and Analysis

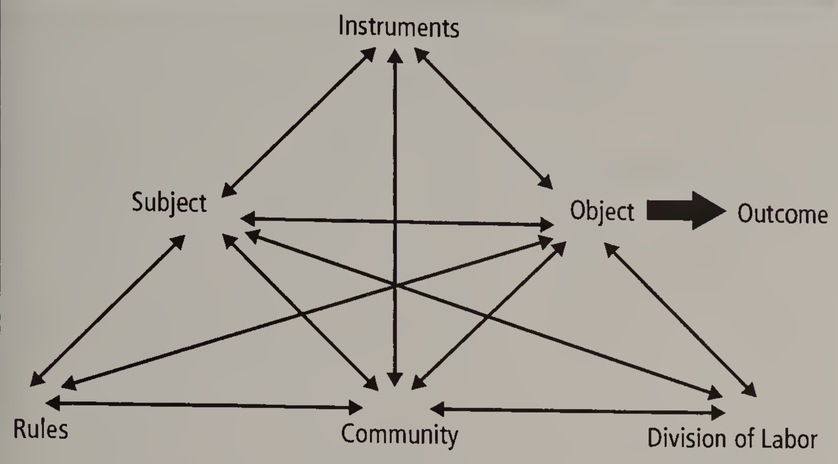
Data were collected in the Ali's home for a year, with intense collection occurring over a three-month period, from July to October 2007. Qualitative data collection methods and materials included audio and video recorded structured, semi-structured, and unstructured interviews; participant observations; a guided "digital walk" (a guided tour to locate all of the digital tools in the home); digital photos; email discussions; transcriptions; and artifacts, such as Gerard's report card and illustrations, and Larnee's essays prepared for her G.E.D. classes. Field notes provided relevant segments of digital literacy practices in the home. Interviews were conducted at the beginning and end of the collection phase for an average of 60–90 minutes with Larnee, and 30–60 minutes with Gerard, with frequent breaks as needed.

Data analysis occurred continually and recursively across phases of the study to locate gaps and patterns in the data. Interview transcripts, audio/videotapes, and field notes were analyzed with and without the audio to identify themes and patterns in the data, and an "open coding" scheme was developed to code transcripts (Miles & Huberman, 1994). Color-coding was also used for each research question and inquiry.

Data were analyzed based on Activity Theory (Engeström, 1987, 1999; Vygotsky, 1978) in order to examine the structure of human activity in the home. This theory accounts for how individuals mediate multiple environments, communities, artifacts, etc., within an activity system. The theory allows the researcher to explain the tensions and contradictions that arise within each element of the activity system in order to "understand everyday practice in the real world [as an] objective of scientific practice . . . the object of activity theory is to understand the unity of consciousness and activity" (Nardi, 1995, p. 3). Activity theorists suggest that technology use can be viewed as an "activity situated within communities of practice or activity systems" (Chandler-Olcott & Mahar, 2003, p. 361). In fact, Wenger (1998) argues that, "Having a tool to perform an activity changes the nature of that activity," and that "participating in the changed activity always changes the members of the community" (p. 59). For initial analysis, I explored and charted how this family utilized digital literacies in the home, and how those tools were used within seven activity systems (subject, artifacts/tools, object, rules, community, division of labor, and outcome) as described below.

Activity theory provided a reputable lens to explore digital literacies as social practices because it offered a heuristic framework of activity and thinking about the "interconnection of modes" while calling into attention meaning making (Jewitt, 2006, p. 23). Activity Theory is situated in a Cultural-Historical Activity Theory (CHAT) approach to learning and is based on Vygotsky's theory of learning as a socially constructed activity. This method was used to

Figure 2. Seven Activity Systems



Center for Activity Theory and Developmental Work Research (2003–2004)

examine the relations between objects, tools, and signs, that is, exploring how an individual's interaction with mediating tools (e.g., computers, cell phones, communication)—physical or mental—can achieve a particular outcome (see Figure 2).

Figure 2 presents an extended model of the seven activity systems. The *subject* (human agent) is the person for whom the activity was created or the person undertaking the activity; the subject is usually the point of focus in the analysis. The *object* (problem or purpose) refers to the "raw material" or "problem space" where the activity was motivated, directed, or given a shape "that meets a human need," and that played a role in the *outcome* (Center for Activity Theory and Developmental Work Research, 2003–2004). These *activities* are mediated by the *artifacts,* (instruments/tools), that have a profound impact on the subject's thinking and experience during the activity. The activity is also mediated in the context of the *community* where the activity was carried out (Lloyd & Cronin, 2002). In any activity there may be constraints based on what an individual can or is permitted to do that determine what *rules* were made, and what *division of labor* (roles) should be taken that mediate the interaction in the activity system.

Multimodal discourse analysis (MMDA) draws on the multimodality of mediated actions outside of spoken language that carry meaning (e.g., gestures, visuals, sounds, etc.) (Kress & van Leeuwen, 2001; Scollon & Levine, 2004). The use of MMDA was based on the assumption that meaning is made, interpreted, distributed, and received through many representational and communicative modes (Kress & Jewitt, 2003). Each practice that Larnee and Gerard engaged in recruited multiple modalities that communicated unique kinds of meaning. I argue that one cannot fully understand a practice (e.g., playing videogames, IM, texting) unless one is able to read the signs of how meaning making is construed. I used MMDA to prepare a table to provide a condensed version of Larnee and Gerard's texting and IM (see example in Table 1).

Using tools from MMDA I modified Wohlwend's (2007, 2009) table to describe how Larnee and Gerard used texting and IM as means for social interaction through the use of a cell phone and computer. I chose relevant data to document how the use of texting and IM was significant and influenced their relational practices. I labeled column one, *Scene*, to represent each interaction. The second column, labeled *Time*, shows the quick turn of events within each activity (e.g., the time Gerard used to read the IM while Larnee texted). I labeled column three *Moment-to-Moment Action/Context* to describe the action that occurred when Larnee and Gerard texted and IM'd (e.g., Larnee texting with one hand and drinking soda with the other hand). The fourth column highlights the *Talk at Each Turn/Verbal Discourse* (e.g., quotes from participants) and the fifth column, *Effect on Action/Practice*, describes the ways Larnee and Gerard's digital literacy practices made an impact on each other (e.g., vocabulary development as Larnee initiated and apprenticed Gerard into the practice). Describing Larnee and Gerard's texting and IM practices through MMDA allowed me many ways to think about, understand, and analyze the mother and son relationship and also, to note how they used multiple modes, along with discourses, to answer my questions. Therefore, using MMDA captured the often significant and unnoticeable nuances beyond language that were present and carried out in Larnee and Gerard's lives. The findings are presented below.

Table 1. Multimodal Discourse Analysis (MMDA) Chart of Larnee and Gerard's Practice of Texting and IMing

Scene	Time	Moment-to-Moment Action/Context	Talk at Each Turn/Verbal Discourse	Effect on Action/Practice
1	0:29:09:02	Gerard is sitting to the left of the screen counterclockwise and is looking at the computer screen. His right hand is on the mouse and his right foot is on the computer unit on the floor. Larnee's right hand is shown holding her cell phone and is texting Gerard. She appears to be leaning back with a mug in her left hand.	L: This is pretty much an average day right here, for real. Once we get all of the formalities out the way, this is what we do. (laughs)	Larnee initiates and apprentices Gerard into the practice.
2	0:29:29:11	The back of Gerard's chair faces the right side where Gerard cannot be physically seen. Larnee's position is the same.	'L: It's more structured then. [regarding the children playing on the computer in the summer vs. fall]	Larnee is comfortable in this space. Gerard shows agency, owning his practice.

FINDINGS

Texting and IMing As Normal Digital Literacy Practice in a Literate Home

Larnee's bedroom was the hub of her family's digital literacy practices. There, literacy practices such as talking on the phone, emailing, creating print/digital comic strips, creating digital calendars for family members, playing video games, and designing blogs revealed "taken for granted" digital literacy practices. Larnee and her sons created sacred and active spaces of individuality and collectivity that were situated in the Ali household. According to Larnee, she and Gerard have a close relationship, and he is the one who identifies with her fascination with digital literacies. *"He is a major reflection of me"* (Interview, 2007). Gerard frequently came home from school to work on his digital comic strip on the computer and communicate face-to-face with Larnee. In this digital space, they fostered a community of practice (Wenger, 2005). She and Gerard chose to extend their verbal exchanges to more innovative ways to engage beyond talk.

During my interview with Larnee she told me how she engaged in texting and IM with Gerard on a regular basis. Larnee recalled *"Texting is personal . . . If my sons are online, I'll message them and IM from my bed and have a conversation." "And you all are in the same room?"* I asked. *"Same room,"* she stated. According to Larnee there was a need for her to text for quick responses or if she was ill.

In August 2007, for about ten minutes, I observed Larnee, sitting on the bed sending various text messages to Gerard as he sat at her computer desk less than two feet away. As told by Larnee, *"This is pretty much an average day right here, for real. After we get the formalities out the way, this is what we do. We can do this for hours."* Larnee chose to initiate communication with Gerard from her bed via her cell phone. She sent him a text message that appeared as an IM on the computer, and he responded. There was often the in-between, real-time of sending, receiving, and waiting for a text/IM when both simultaneously typed. The content of the text and IM were mundane communication, such as, *"what are you doing," "looking for sprites* [computer graphics]," and Larnee's occasional *textese* to try to throw Gerard off in her usual playful manner (e.g., *ttyl = talk to you later; LOL = laughing out loud*).

During my observation, I asked Larnee questions about her use of texting and IM with Gerard: *"How did you initiate the texting/IM discussion online?" "Did Gerard have any difficulties understanding the IM acronyms?" "What did this practice do for you?"* Prior to Larnee and Gerard texting and IM, Gerard occasionally stood next to his mother and watched her IM friends and family members and asked her what certain acronyms meant. Based on my observations, Gerard appeared to remember the acronyms, and when Larnee decided to text him one day, Gerard responded. I was present on another day when Larnee recalled the time that Gerard first began to use IM to communicate with her, providing an additional answer to my questions.

L: *You know what I wanted to ask you. How did you start figuring out the IMs that I sent? I don't spell the words out . . . How did you start putting them together?*

G: *All I did was just look . . . Look and think.*

This practice became automated; Gerard was able to understand the practice and communicate with Larnee. They took the complexity out of digital literacies and naturalized texting and IM as a normal part of their engagement and communication (Lewis & Fabos, 2005). This back-and-forth practice of virtual and nonverbal communication (typing on the computer, texting, proximity of the practice, and their reliance on the digital tools) may appear to be insignificant since Larnee and Gerard were in the same room at the same time in close proximity to one other. Thus, I reflected on the following inquiries: Why did Larnee and Gerard feel that they needed to text and IM rather than communicating face-to-face? How did this interaction influence the dynamics of family structures in their home? When asked, Gerard responded, *"I text because it is a way for me to be with my mom."* In previous publications (Lewis, 2009, 2010a, 2010b, 2011) I explained the many layers in Larnee's past, including physical and sexual abuse, and how she used this digital literacy practice as a mediating tool to make sense of her life.

Larnee mentioned earlier that she becomes emotional when using technological tools. For instance, while explaining the functions of the computer motherboard she began to discuss the motherboard as being a part of her. She touched the unit explaining what each function meant to her. During one observation she began to cry when one part of the equipment reminded her of a roadblock in her life, of being taken out of school by her mother. She embodied the tool as it became an emotional tie. Pointing to the computer motherboard equipment she said, *"That's a roadblock for me because I haven't completed school. It's not my fault that I wasn't in school; I was taken out of school."* She used this tool as a means of surviving her past and described her need to use digital literacies to communicate with Gerard in online spaces even when she needed to rest due to her illness. Larnee offered her essential reason for texting Gerard.

> *I started doing it [texting] because I didn't want to disturb him from his peaceful state. I started asking him questions to test his knowledge of the computer. Then, the #1 reason, bed rest. I am always on bed rest [due] to my illness, and I wanted to have a way to communicate with him that would make it fun. We text to stay connected to and spend time without us interfering in each other's space."* (Email, 1/16/08)

Larnee and Gerard made digital literacy practice relevant to the use of time and space and in the ways they chose to communicate in their home. Thus, their literacy practices demonstrate the affordances of digital and multimodal literacies: for engagement, awareness, connectivity, and communication. In the next section I address the broader topics of what it means to be literate in this digital world, outside of talk, and how meaning is made and mediated through the activity systems which were a relevant part of Larnee and Gerard's digital lives.

Texting and IMing As Meaning-Making and a Mediating Activity System

Larnee and Gerard's digital literacy practices of texting and IM demonstrated how engagement beyond talk can be primary sources of communication between a mother and son. Kress (2003) suggests that, "language alone cannot give us access to the meaning of the multimodality constituted message; language and literacy now have to be seen as partial bearers of meaning only" (p. 35). In other words, what occurs beyond language, via modes, is equally, if not more, prominent in these digital literacy practices. During my observations of Larnee and Gerard texting and IM, Gerard neatly positioned himself in front of the computer, his right hand on the mouse to maneuver the screen. He moved the computer screen windows on the monitor back and forth on the Internet browser from collecting and transporting sprites (e.g., computer graphics), to working on a digital comic strip, to looking at his mother's texts. At times, I heard very little talk, only the sounds of Gerard fidgeting with the mouse scroll wheel or the short beeping sounds when Larnee typed, or a beep to inform Gerard when he received an IM. Gerard used each mode to make meaning and connect to what Larnee was doing. Figure 3 presents a video still detailing how the multiple modes of representation gave credence to how Gerard and Larnee engaged in texting and IM as well as how this activity became a meaning-making practice.

Figure 3 highlights the way Larnee and Gerard interacted through texting and IM. By maneuvering back and forth they gained agency at home. I adopt Moje and Lewis's (2007) description of *agency*: the "strategic making and remaking of selves, identities, activities, relationships, cultural tools and resources and histories, as embedded within relations of power" (p. 18). Larnee and Gerard kept *remaking* themselves in the practice of texting and IM to make sure it made sense to them. For instance, they felt competent and liberated as they constantly drew on a range of

Figure 3. Larnee and Gerard Texting and IMing As a Meaning-Making Practice

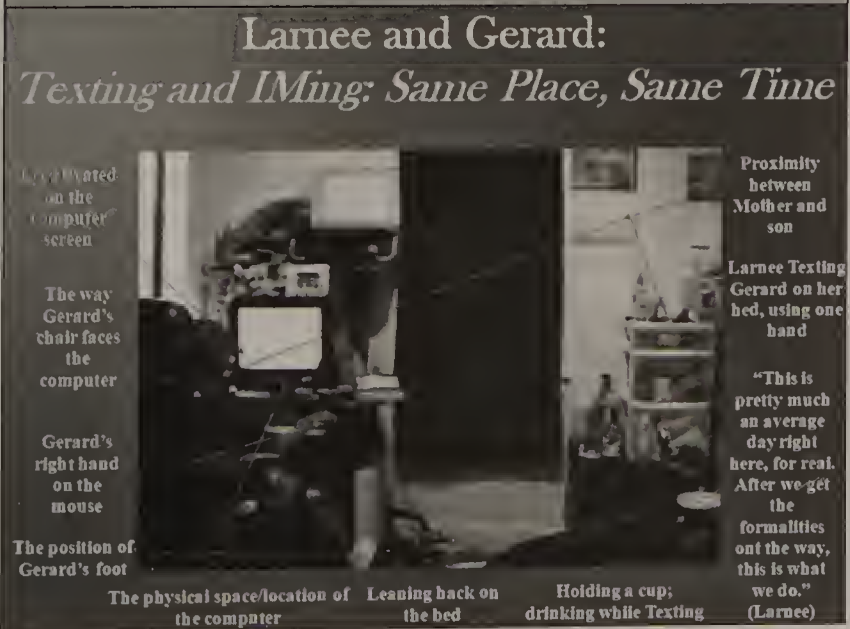
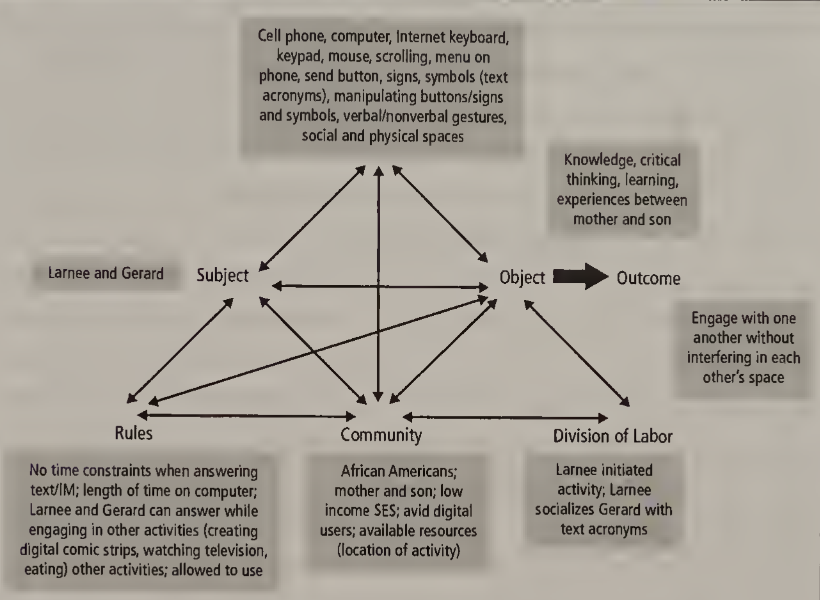


Figure 4. Larnee and Gerard's Activity Theory System



(Adapted from Center for Activity Theory and Developmental Work Research 2003–2004)

modes (linguistic and nonlinguistic) during texting and IM to create, interpret, produce, and make meaning. The typing on the keyboard, the beeps from the cell phone with overlapping exchanges, second delays, and proximity gave them the agency to create new ways and new activities that gave them a sense of self.

The video still in Figure 3 suggests that the idea of *semiotic resources* ("the resources of and for making meaning") (Jewitt, 2006, p. 16) is also central to the interpretation of how Larnee and Gerard connected with each other on computer and phone screens, what they did with images, how ideas were expressed and displayed with images, and what they did in practice (Jewitt, 2006; Jewitt & Oyama, 2001). Larnee and Gerard became transformers of what, how, and why they used texting and IM to communicate with each other. They were able to understand the same code in order to connect signs and meanings. They selected from a range of semiotic resources that expressed meaning in the way they communicated from screen to phone and connected meanings to the sounds (e.g., sound indication when each received a text or IM) or graphic designs/patterns in order to understand each other online. In addition, Gerard often engaged in creating his digital comic strip and chose to respond to Larnee after he switched/changed a screen or found a sprite for his comic strip. The activity theory chart below highlights Larnee and Gerard's structure of human activity in the home.

In this diagram I represent Larnee and Gerard as the *subjects* of this interaction. I highlight the *objects* as the motive of the activity (physical or mental), the knowledge, learning experiences, and the critical thinking skills that were developed during their interaction. I chart the *artifacts/mediating tools* as the cell phone, computer, social and physical spaces, keyboard, nonverbal/verbal gestures, and text acronyms that were mediating the activity and assisted in achieving the outcome of their interaction. The *division of labor* or roles helped to shape the activity by the subjects and the

community in which they are practiced. For instance, Larnee was the initiator of most of the digital literacy practices in the home; therefore, she had a primary role in managing the practices. Gerard also had a role in deciding to participate by answering the text or not. The *rules* positioned Larnee and Gerard in a communal space in which they created norms in which to engage in texting and IM. For example, Larnee supported the activity in her bedroom, where the only computer was located, but at any time she could impose rules on the length of time Gerard spent on the computer and in her bedroom. She chose how long to engage in texting and IM, which acronyms she chose to introduce to Gerard, and required that his homework be completed before working on the computer. It was the unwritten, unspoken discretions and norms that she afforded to Gerard that could be carried out in the activity (e.g., freedom to take his time to respond to her text or choosing to engage/disengage in the activity). Thus, the overall *outcome* from this digital literacy practice was engaging with one another without interfering in each other's physical spaces.

The study of texting and IM as a meaning making and activity theory system explored the various modes used, practiced, and interpreted beyond talk, resources, and contexts. The relationship between these two entities, meaning-making and activity theory, became central approaches to understanding how Larnee and Gerard, as transformers and sign makers, made choices regarding how and in what ways to respond to each other. Aside from creating a fluid practice of "*I text and IM the way/when I want to*," Larnee and Gerard engaged in the unwritten and unspoken norms that caused me to look at the meaning making practice 'beyond' the individual and concentrate on how the practice was situated within a social activity system (Kress & Jewitt, 2003).

DISCUSSION AND CONCLUSIONS

This study describes how an African American mother and son communicated with each other via texting and IM that helped to shape their family relationship, draw on multimodal meaning-making resources, and change the dynamics of family structures. Texting and IM were 'normal' practices for Larnee and Gerard, and reinforced Barton and Hamilton's (1998) argument that "people learn new literacies throughout their lives and incorporate new technologies into their everyday activities" (p. 263). These practices were vital to how Larnee related to and with Gerard. She initiated a social network to foster further discussions and enhanced communication skills and interactions between her and Gerard using tools that were of interest. This is not to suggest that Larnee and Gerard favored digital literacy practices over other forms of communication with each other, but the study offers insight into various ways of communicating using digital tools.

Having digital tools in the home may shift families' relationships toward more cyber connections (and possibly fewer face-to-face communications). Families like the Ali's may also unconsciously displace traditional practices such as conversing over dinner together and expand opportunities to engage in discussions throughout daily activities. These literacy practices tie into Taylor's (1983) argument that there is no single definition for family literacy because it is based on the collective literacies that occur in family members' everyday lives.

As researchers we are compelled to make sense of how digital literacy practices speak to a larger interpretation of multimodal semiotic approaches. The use of digital tools offered the Ali family alternative channels for communication. Larnee and Gerard's digital literacy practices relate to 21st century skills of communicating information through multiple modes of meaning (Kress & van Leeuwen, 2001). Further research is needed to examine what is lost and what is gained in terms of nonverbal cues from communicating via phone or Internet, versus direct personal contact generated by what families say and do (e.g., facial expressions, emotions in tone).

Larnee and Gerard's interaction with texting and IM suggests that a mother and son's individual and collective knowledge and learning were not constrained, unlike other homes where some families may not utilize the new literacies and digital technologies that extend the family structure. The practice of texting and IM acknowledged the nonverbal and verbal occurrences, which presented new ways of communicating in homes and schools in the 21st century. More specifically, Larnee encouraged and initiated her own and Gerard's funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992) by acknowledging their digital literacy practices and unnoticed spoken, written, and gestural nuances as salient in their household. They were able to introduce and learn beyond the practice of texting and IM but accomplish this through simultaneous use of various modes of representation and communication, which offer substantial contributions to enhancing learning in academic settings.

Yet, this study also revealed evidence of the power relationships that impacted Larnee and Gerard's interactions in areas of awareness, apprenticeship, and agency (Lewis, 2011). However, it was clear that digital literacies were central to the relational bond between Larnee and Gerard and to the ways the mother created an awareness of digital tools that revealed her role as initiator and communicator in her online community. Unlike the uneven relational power of some shared storybook reading in families, by using digital literacies this family's relationships became more symmetrical in terms of expertise.

Apprenticeship and guided participation were evident when Larnee helped Gerard with his digital comic strip. Rogoff (1990) reminds us that apprenticeship occurs when individuals are involved in a social activity that supports a child's "understanding of [a] skill [by] using the tools of culture" (p. vii). When Gerard received an IM from his mother, he responded to her in the midst of completing his digital comic strip. Since Larnee offers strong support for her children's learning, she allowed Gerard the responsibility of using the computer on his own, but she also recruited Gerard to join and manage his participation in IM as he was apprenticed into these engagements for communication and social transformation (Tierney, Bond, & Bresler, 2006). Maneuvering back and forth between texting and IM gave Gerard authority and agency at home.

Larnee showed evidence of agency in how she used her knowledge and skills to engage in and understand these digital literacy practices despite the fact that she had not obtained her G.E.D. Outside of the relationship she had with Gerard, she also had a "relationship" with the digital tools that was the result of her traumatic past. By initiating digital literacy practices in her home she felt empowered, giving her the agency she never received as a child. These practices reinforce Turkle's (2005) concept of *second self* and the importance of considering not only what the digital tools do *for* us, but also what they do *to* us. Thus, Larnee's agentic roles were demonstrated in how she made and remade herself, created a learning space, introduced new practices and skills, and engaged in varying discourses with Gerard. Given the complex and unique practices that were demonstrated in Larnee and Gerard's home, further research is needed to explore how family literacy practices emerging from this study can help shape other families' digital lives. In the section below, I revisit some of the major points explored in this article to consider implications of new insights into family's digital literacies and respond to how we need to make sense of these practices in families like Larnee and Gerard within broader family and research contexts.

New Insights into Family Digital Literacies

Larnee and Gerard's histories, experiences, values, and belief systems surrounding digital literacies reflected their everyday practices and were constantly constructed and reconstructed as they used digital literacies as mediating tools to help make sense of their lives. With only one computer in the home, they collaborated by texting and IM as a normal literacy practice. Their interactions with one another around digital literacies not only encouraged and supported family relations but also, afforded them unique learning relationships.

While researchers have provided substantial information regarding family literacy practices, the increasing technological advances in society have changed how today's family members communicate and interact with one another. Digital literacies have become increasingly important in the ways families communicate, disseminate information, read, write, learn, enjoy, and cope, as well as perceive literacy. Within this vein, I reflect on and offer types of insights for exploring family's digital literacy practices in this space and time: *families' digital literacies as ecologies, families' digital literacies as deictic,* and *families' digital literacies as an emotional factor*. Each category responds to the ways families' digital literacies have shifted over time and suggests how researchers can position and study digitally-literate families.

Families' digital literacies as ecologies. For twenty-first-century families, being literate means engaging in digital literacies. Today's families have welcomed digital tools (i.e., texting/Facebook) and accompanying literacy practices into their homes and lives, so a substantial amount of some families' time is now mediated through the Internet. As a result, digital literacy practices are evolving and shaping some families' daily practices and the context for family interactions. Such practices inform families' digital identities that extend over time.

Just as Larnee and Gerard engaged in a plethora of digital literacy activities such as texting and IM, practices like these would not have been possible if Larnee resisted the opportunity to create a hub for digital tools and practices in her home and thus, in the lives of her family. Families' digital literacies need to be thought of as larger literacy ecologies within social and cultural contexts. For instance, Steward (1972) described a cultural ecology approach through the relationship and adaptation between nature and culture in human societies. Cooper (1986) argues that an ecological framework situates literacy as "an activity through which a person is continually engaged with a variety of socially constructed systems" (p. 367). In addition, Brooke (2009) explores "ecologies of practice" as a "conscious, directed activity" (p. 6) that explores how new media serves as interface rather than object. For instance, Brooke suggests how the study of social network sites, through ecologies of practice framework, relies on continuous literate activities that occur on the sites rather than the actual text created through them (Buck, 2012). Pahl and Rowsell (2012) depict ecologies as multiple literacies, tools, and resources that exist and take root by individuals' actions that accumulate and relate to other practices. The analytical attention to ecologies provides us with a greater understanding of how families' digital literacies are no longer traditional, but viewed as ecologies that are fluid and continually circulating across a range of spaces. This understanding fortifies the importance of families' uses and purposes of digital literacy practices in the digital age. In this vein, examining families' digital literacies as ecologies also reveals the multiple ways family members communicate, engage, and relate in the home through deictic styles and forms.

Families' digital literacies as deictic. As Larnee and Gerard texted back and forth with each other in Larnee's bedroom, they drew on a range of modes, outside the traditional, to make meanings and establish these practices as "typical" in their home without interfering in each other's physical spaces. However, they engaged and welcomed each other in their digital spaces. This is one example of the evidence that suggests that literacy practices are changing. Thus, there is a need to identify, redefine, and reshape the concept of literacy because of the social demands, roles, and functions of the new kinds of digital technologies that are accessible and influential (Leu, 2000; Lewis & Fabos, 2005). Thus, literacy becomes deictic (Leu, 2000); according to Leu (2001), "literacy is increasingly deictic—the definition of what it means to be literate continuously changes as new technologies of literacy rapidly appear in an age of information, creating both new opportunities and new challenges for literacy educators" (p. 54). Families create deictic relationships that are developing between literacy and digital literacies and practices in the ways they choose to communicate verbally and virtually. Studying only face-to-face conversations becomes limited when other multimodal modes (linguistic, auditory, visual, gestural, and spatial) blur the boundaries of how we examine literacy in this age. These newer practices open up spaces for family members to extend their communication practices and discussions via digital tools in new ways. Through these investigations we can begin to

answer inquiries regarding the affordances and disaffordances of what is lost and gained when families communicate via digital tools versus personal contact.

It is important, as well, to help families to recognize and own their digital literacy practices that are embodied and supported in their homes as everyday literacy practices. In the future these practices will maintain extended family traditions, as well as intergenerational, multilingual, and multimodal literacies. However, it is important to recognize that engagement in digital literacies, for some family members, extends beyond the deictic literacy practices to fulfill an emotional need or desire in order to cope with past struggles.

Families' digital literacies as an emotional factor. Larnee had an attraction to and reliance on digital literacies/tools. She felt comforted when she connected with Gerard on her cell phone. She slept with her cell phone next to her, and she embodied certain digital tools within herself and as parts of her body (e.g., computer motherboard as self; C drive as the brain) (Lewis, 2009). She used these tools as a means to survive her past abuse or as an exchange between the digital tool and the members of her family. In addition, during my first interview with Larnee and later when she blogged with Gerard, she said *"technology is emotional for me"* stating, *[we] "intertwine, interact, and join with one another and become unified as one. If that is not what you would call emotional then..?"* Larnee also admitted her passion for texting as *"personal and emotional."* She explained this need:

> *Ooh, texting is personal. I think it's more personal than an IM because not too many people use your phone to view your text messages, only to make a phone call. Text messages are something that people normally do to get emotional with the person.* (Semi-structured interview, 7/24/07)

Viewing a family's digital literacies as *emotional* can play a significant role in their understanding of how digital literacy practices influence the ways they make sense of themselves. In an NPR interview (Gross, 2012), Turkle (2012) argued *"it's a way of life to be always texting."* Referring to her 2012 book *Alone Together: Why We Expect More from Technology and Less from Each Other*, Turkle added the fact that there is an emotional dependence on digital devices that individuals cling to that affects how they communicate with one another. Turkle stated, *"What is so seductive about texting, about keeping that phone on, about that little red light on the BlackBerry, is you want to know who wants you"* (Gross, 2012). Larnee's choosing to engage in, and create digital literacy practices with her son in order to interact with him stemmed from her history of physical and sexual abuse and past experiences that motivated her to create agency and ownership in her current situation (Barton, Appleby, Hodge, Tusting, & Ivani , 2007; Moje & Lewis, 2007). Thus, this information calls attention to the ways digital tools influence and shape what individuals do with them and suggests how individuals influence and shape digital tools to become a part of their agentic and identic selves. As a result, family members who create emotional attachments to digital tools affect their social relations and practices (Lewis, 2009, 2011).

These categories, *families' digital literacies as ecologies, families' digital literacies as deictic,* and *families' digital literacies as an emotional factor*, describe significant shifts and insights from traditional literacy practices. A family's digital literacy practices can make it possible for members to compete in a society with increasing technological demands as well as secure family relationships and structures in the home. As a result, I classify these categories as distinct ways in which a family's engagement with digital literacies will continue to change family dynamics and relationships in the home.

LIMITATIONS

Studying Larnee and Gerard's rich digital literacy practices, such as texting and IM, offered a detailed and situated representation of the implications of a family's digital literacies. However, there is no indication of how widely this family's practices represent any larger group or how they relate to another family's practices. Rather, the work is presented as an initial inquiry and an important area for future research. In addition, because some documentation from Larnee and Gerard's texting and IM activities were unfortunately deleted as a result of their computer crashing, I relied on the live interactions during the data collection and observations to gather the data that were analyzed. A subsequent study could reverse the effects of this problem.

Some of the constraints relate to ethnographic insights regarding methodological procedures. For instance, my identity as an African American and a former reading specialist at Gerard's after-school program affected the dynamics of our in-home and in-school interactions, and heightened my role as a researcher because I had rapport with them from various perspectives across their lives. I did not examine Gerard's learning practices in the mainstream classroom, although I acknowledge that they might have had an impact on his learning at home, as well as his identities, apprenticeship models, and agentic roles. Although I was aware of possible affinity spaces/groups and communities of practice, I chose to focus on the context of home since studies such as the one I conducted on a family's digital literacies surrounding texting and IM, in particular for a family of color, are rare in the literature.

Although Gerard had three male siblings, I chose to profile Larnee's and Gerard's texting and IM roles separately. As explained earlier, Gerard's digital literacy practices were the impetus that first drew me to consider him as a participant for the study. Extending the study over a year or two would possibly have allowed me the opportunity to examine more interactions with the entire family and their friends to fully explore how the family's digital literacy practices influenced their relations with other members of the family and community. My decision to limit the study to the observation of a single dyad allowed me to gain a deeper understanding that will inform future inquiries in more extended contexts.

In summary, this study represented family literacy in unique and complex ways as it reveals how an African American mother and son used texting and IM, how they drew on multimodal meaning making resources, and how their interactions changed the dynamics of their family's structure. Larnee and Gerard's digital literacy practices suggest how meanings are made over time in digital and non-digital contexts, revealing how these family members communicate in the rapidly changing literacies of the twenty-first century. One future research goal is to explore larger samples of families' digital literacy practices in order to understand how other families interact with digital literacy practices in their home. Finally, it is important to broaden this understanding by investigating digital literacy interactions between parents, students, and teachers in order to provide critical insights for researchers and educators who seek to enhance and explore digital learning environments.

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Learning about the Literacy Development of English Language Learners in Asynchronous Online Discussions

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ABSTRACT

The present study examined asynchronous online discussions in the online course "English Language Development" to identify themes related to teachers and teacher candidates' learning about the language and literacy development of English Language Learners (ELLs) when they facilitated online discussions. Our overall goal was to determine whether teachers and teacher candidates developed sufficient understanding to effectively educate ELLs. Participants were 29 teachers and teacher candidates who were enrolled in the course in the fall semester, 2011 at a large research university in Indiana. The following research questions were addressed: 1) What do candidates identify as key issues for the literacy development of ELLs when they facilitate online discussions? and 2) In what ways did they discuss these key issues in the online environment? The analysis of teachers and teacher candidates' weekly online discussion postings (n = 154) indicated that student-discussion facilitation can impact the levels of teachers and teacher candidates' understanding about the literacy development of ELLs.

INTRODUCTION

The number of English Language Learners (ELLs) in the United States has steadily increased over the past several years and now comprises more than 10% of the K–12 student population (National Clearinghouse for English Language Acquisition, 2006). These students are often mainstreamed and therefore, receive support from non-specialist content area teachers who may not have had any preparation to work with them (Gándara, Maxwell-Jolly, & Driscoll, 2005). All teachers need to be prepared to work with these students, not just language teachers who provide support in specialized English as a Second Language or bilingual programs (Lucas & Grinberg, 2008).

Between 1994–95 and 2004–05, Indiana, the context for this study, had the third highest rate of growth in the number of ELLs in the entire United States, or 408%, while the overall enrollment in Indiana schools declined 5% (NCELA, 2006). This relatively new student population places demands on teachers to know how to work with them. One of the most important areas of focus is ELLs' language and literacy development. To address this major need in Indiana, Midwest University (all names are pseudonyms) designed a new English Language Learning (ELL) licensure program, offered through distance education, that focuses specifically on the preparation of mainstream content area teachers to work with ELLs.

As distance education has grown in the world, implementation of effective online programs and courses has become a vital part of the learning process at many universities. Learning at a distance by means of electronic communications implies another concept of learning; researchers refer to it as *"transactional distance"* to define relationships of instructor and learners who are separated from each other physically and geographically (Moore, 2007). Increasing numbers of universities have implemented a variety of successful online programs and courses.

The "beating heart" of online course activities is considered to be asynchronous online discussions (Sull, 2009, p. 65), also referred to as the "central hub" (Dennen & Wieland, 2007, p. 281). Studies have found that asynchronous online discussions can support students' active learning, help them construct their own knowledge, and enhance rich interactions between students and instructors by removing transactional distance when teaching and learning occur in separate locations (Klisc, McGill, & Hobbs, 2012; Means, Toyama, Murphy, Bakia, & Jones, 2010; Moore, 2007; Romiszowski & Mason, 2004). We draw on a larger investigation that focused on student-discussion facilitation and its role in candidates' understanding of ELLs. For the present study, we examined asynchronous online discussions in the course, "English Language Development," to identify themes related to candidates' learning about the language and literacy development of ELLs when they facilitated online discussions. We asked the following research questions: 1) What do candidates identify as key issues for the literacy development of ELLs when they facilitate online discussions? and 2) In what ways did they discuss these key issues in the online environment?

THEORETICAL FRAMEWORK

Preparation for Teaching English Language Learners

Teaching academic subjects to students concurrently engaged in the process of learning English is a complex endeavor (Lucas, Villegas, & Freedson-González, 2008; Schleppegrell, 2004). In mainstream content area classes, English is the medium of instruction and the language used in textbooks and class materials. Literacy is particularly significant in this frame because it is a process that can enable and mediate all other subject matter learning. Supporting ELLs to be readers and writers in the context of mainstream classrooms is a matter of social justice (Darling-Hammond, 2002). To support ELLs' literacy development, equitable access to the curriculum, and opportunities to participate in a democratic society, mainstream teachers need to be prepared to know how language

works, to focus on reading comprehension, and to critically evaluate the texts they encounter (Lucas & Grinberg, 2008; Schleppegrell, 2004).

When educators become certified to teach content courses, their knowledge base may include an understanding of content; pedagogy; curriculum; learners and learning; contexts of schooling; pedagogical content knowledge; and educational philosophies, goals, and objectives (Shulman, 1987). All teachers, regardless of their content area(s), also need to understand how language can become a tool for learning (Mohan, 1986; Schleppegrell, 2004) and to acknowledge that language and literacy are central for learning (Halliday, 1993). In Halliday's words, "language is the essential condition of knowing, the process by which experience *becomes* knowledge" (p. 94). It is frequently through language that students demonstrate their understanding of concepts and information. Without support in learning the ways language functions, ELLs may not have access to content.

Several studies have discussed the role of "funds of knowledge," introduced in 1992 by Moll, Amanti, Neff, and González, which calls for teachers to become familiar with their students' multicultural resources and to accept them as strengths rather than as cultural deficits (Corno, 2008; González, Moll, & Amanti, 2005). By positioning themselves as learners, teachers can understand how to construct a more multicultural pedagogy (Solsken, Willett, & Wilson-Keenan, 2000). The tradition of funds of knowledge invites teachers to step outside their comfort zones to explore their students' lives and to provide culturally and linguistically-responsive lessons (González et al., 2005). Similarly, Nieto (2002) explored the notion of understanding and manifesting multicultural and linguistic issues in the classroom to transform learning in a way that makes it possible for students to create knowledge.

Teacher education programs often include a focus on multicultural education, but this focus will not be sufficient to prepare all teachers for the growing linguistically and culturally diverse student population (de Jong & Harper, 2005, 2008). An add-on approach may affect some but not all pre-service and in-service teachers. Therefore, teacher education programs need to explicitly address linguistic diversity by thoughtfully integrating their knowledge of linguistics and language development into the curriculum (Athanases & de Oliveira, 2010; Lucas & Grinberg, 2008). They need to prepare teachers to develop effective strategies and techniques for developing a second language, differentiating instruction, and working closely with families and communities (Goodwin, 2002). Therefore, asynchronous online discussions may be considered a vehicle for knowledge development since they have the potential to provide these opportunities for the participants.

Asynchronous Online Discussions

By providing time to read and respond to a message, asynchronous online discussions can support the possibility for greater student reflection and critical thinking (Gunawardena, Lowe, & Anderson, 1997; Klisc et al., 2012). However, studies have shown that students participating in asynchronous online discussions often tend to complete course requirements by message posting instead of engaging in a constructive dialogue with their classmates (Dennen & Wieland, 2007). It is still not clear if learning can occur in such online activities. Students more often post their own opinions or reply to their classmates instead of moving the discussion to higher levels of knowledge construction (Garrison, Anderson, & Archer, 2001; Gunawardena et al., 1997).

Therefore, several studies have examined factors that might impact knowledge construction among students in asynchronous online discussions including students' different ways of learning, the design of the discussion task or activity, and the facilitation role or techniques (Hew & Cheung, 2010; Waters, 2012). The majority of studies of facilitation of asynchronous online discussions have focused on an instructor's role as a facilitator to impact students' knowledge construction (Garrison et al., 2001; Klisc et al., 2012). Researchers have agreed that some techniques used by instructors may be effective. For example, online postings from students who were assigned specific roles to facilitate asynchronous online discussions, i.e., summarizer (De Wever, Van Keer, Schellens, & Valcke, 2010) reflected higher levels of knowledge construction because the role of summarizer usually requires a stronger focus on building upon others' contributions and giving new discussion impulses (De Wever et al., 2010). However, studies have found that some students did not want the instructor to facilitate online discussions. They felt that the instructor as a facilitator could be viewed as a form of assessment which makes students hesitant to get involved in voicing their views and opinions (Mazzolini & Maddison, 2003; Zingaro & Oztok, 2012). As a result, some studies have focused on the effectiveness of students' facilitation of asynchronous online discussions and found that student-facilitation may be effective because it is viewed as peer-to-peer relationships. For example, student facilitators who gave comments or opinions, showed appreciation, encouraged people to contribute, and summarized may promote higher level of knowledge construction in online discussions (Hew & Cheung, 2010; Zingaro & Oztok, 2012).

METHODOLOGY

Context for the Study

This study was conducted at a large research university in Indiana with a relatively small program for preparing teachers to work with English language learners. The English Language Learning (ELL) Licensure Program is an additional certification mainly focused on preparing in-service mainstream content area teachers who want to add an ELL certification to their existing licenses. The program also enrolls some pre-service teachers nearing the completion of their primary certification program. Most of the teachers and teacher candidates are monolingual White females. The program admitted its first teacher candidates in fall 2009 and the program is steadily growing. This certification requires 12 credit hours, or 4 courses, that are very time-intensive, packed with content, and offered online. Candidates have various opportunities to

observe and work with ELLs in a variety of contexts since all field experiences are integrated within each of the courses. Both program faculty and school-based teachers with whom candidates are working supervise field experiences. The course in which the data for the current investigation were collected is entitled "English Language Development." The course instructor was a Latina and a specialist in ELL who taught at the university from 2006 until summer 2013 and was responsible for all aspects of course development and delivery. The teaching assistant was a Ph.D. candidate in learning design and technology at the time of the study and helped with course management.

"English Language Development" focuses on the language development of ELLs from ages 0 to 18 and beyond. The course was divided into 5 modules: 1) Multilingual students in the U.S.; 2) Language development and education in ages 0–9; 3) Language development and education ages 9–18 and beyond; 4) Culture and the literacy development of ELLs; and 5) The Role of the teacher in the ELD of ELLs. The two main course readings are Menyuk and Brisk (2005) and Valdés (2001). In reading, discussions, and activities related to Menyuk and Brisk (2005), candidates examine the significant changes in language knowledge and use that occur from infancy through early adulthood and how language differences relate to experiential differences. Candidates discuss and learn more about best educational practices for bilingual learners at each stage of language development and plan instruction for diverse students with varying levels of experience and language proficiency. In reading Valdés (2001), candidates gain an inside look at the lives and experiences of four Mexican-heritage children in an American middle school, and learn about the difficulties surrounding the teaching and learning of English for ELLs in that context. In addition, teachers and teacher candidates read, discuss, and engage in activities focused on second language development, differentiating literacy instruction, and working closely with families and communities, all related to a number of other relevant scholarly publications.

Asynchronous online discussions are a major part of this course as they support teachers and teacher candidates' active learning and construction of knowledge about literacy and language development of ELLs. Online discussion can develop rich interactions between teachers and teacher candidates and instructors. This was one of the pedagogical goals for the course from which the data for this study were collected. Another pedagogical goal was to increase participation in asynchronous online discussions by structuring them so that participants led the discussions themselves. Ultimately, the main pedagogical goal was the development of candidates' knowledge about the significant changes in language knowledge and use that occur from infancy through early adulthood, their connections to culture, as well as the best educational practices for ELLs.

Participants

Twenty-nine teachers and teacher candidates were enrolled in the course in the fall semester, 2011. They included pre-service teachers, in-service teachers, special education instructors, and Master's and Ph.D. students in literacy and language education and related areas. Their language backgrounds included Bulgarian, Chinese, English, Greek, Hindi, Korean, Russian, and Spanish. Participants' teaching contexts varied with a preponderance of lower income suburban and rural communities, with culturally diverse students and high numbers of ELLs in schools and classes.

Data Collection and Analysis

Data were collected throughout the semester through Blackboard, the course management system used to deliver online instruction. We collected teachers and teacher candidates' weekly online discussion postings in the online course "English Language Development" for 16 weeks, the duration of the semester. Teachers and teacher candidates worked in four groups of eight. Each week, each group had an assigned discussion leader who was responsible for developing a question based on the readings for the week, writing a summary of the readings, responding to at least five teachers and teacher candidates in the group, and submitting the summary of discussion postings. Each group read the same weekly readings but responded to different types of questions developed by their leaders. Each participant was required to submit an initial post answering the weekly question(s) and respond to peers in the group. Students were not limited in the number of posts, but were allowed to post as many messages as needed. Participation in online discussions constituted 25% of their final grade.

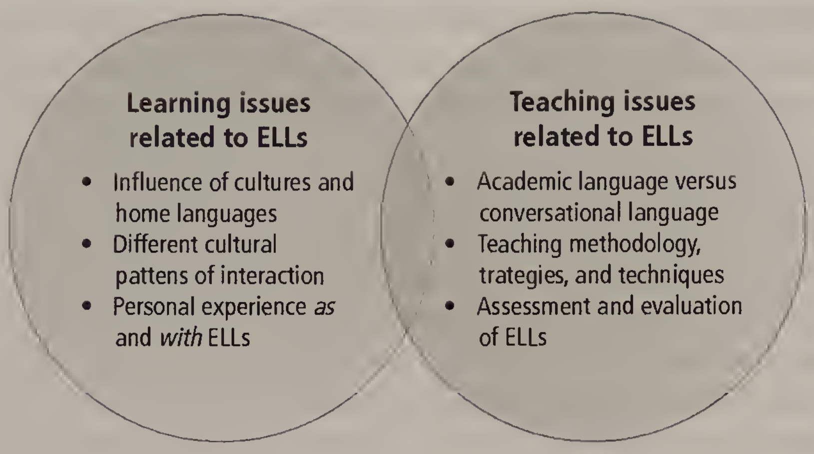
Four discussion threads which occurred in the middle of the semester were more closely examined for this study. These threads were chosen because the online discussions took place closer to the end of the course when the teachers and teacher candidates had already adapted to the online environment. First, we reviewed a total of 154 online postings and wrote up emerging themes. Second, because we were primarily interested in participants' demonstration of their learning about the literacy development of ELLs, we isolated portions of postings concerning these issues. We created data files for each group, in which postings were copied and pasted into relevant cells regarding elements of relevance to literacy development. We continually revised themes until they captured all portions of the data set.

We then examined emerging themes within each of the four groups and looked across the groups to finalize themes. We used the constant comparative method (Merriam, 1998) to analyze teachers and teacher candidates' discussion related to the literacy development of ELLs. In order to capture both patterns and examples, we balanced the summary and quotation (Morgan, 1988).

RESULTS

The analysis of the weekly online postings revealed the issues that were most frequently discussed in each group, as determined by the number of postings on each theme. Therefore, these themes could be viewed as the most interesting to the teachers and teacher candidates. The themes also reflect the overall patterns of occurrence of different themes discussed throughout the semester. The

Figure 1. Themes Related to the Literacy Development of ELLs



analysis revealed two major themes in discussions related to the literacy development of ELLs: learning issues related to ELLs and teaching issues related to ELLs. Figure 1 shows an overview of the themes and their description.

Learning Issues Related to ELLs

Influence of cultures and home languages. Teachers and teacher candidates discussed the influence of culture in ELLs' literacy development. Shanti, a second-year Master's student in Curriculum Studies who is from India, shared her views that teachers should be aware of children's cultures and home languages and should be allowed to use bilingual dictionaries in the classroom. She further discussed the notion of incorporating children's cultures into lesson plans so the content could be better understood. She mentioned some activities to assist ELLs' language development such as word study, reading logs, author study, and book talks. Shanti summarized her thoughts with the idea that "*incorporating diverse cultures into the classrooms would also help the ELLs to feel that are not treated as 'outsiders' and would help them to understand the language in a better way.*" In her response to Shanti, Marina, a Master's student who moved to the United States from Russia, used evidence from the literature saying, "*a student whose culture is respected and voiced in the classroom will have a positive self-esteem, motivation for success, and education becomes meaningful to him/her.*" Like Shanti, Sam, a high school English teacher who grew up in Indiana, discussed some key points from the course textbook about the preparation of teachers for ELLs, including the importance of cultures and home languages. He noted that, "*language acquisition is complicated by the diversity of student-spoken languages and the relative homogeneity of teacher-spoken languages.*"

Furthermore, Sam noted that engaging students' home language (L1) can help them gain a higher level of competency in their second language (L2). To support his arguments, he noted that, "*if the research tells us that we need to engage our students in their L1, we need to make an effort to close this gap that is keeping our non-native English speakers from having equal access to education.*" Echoing Sam in the same discussion thread, Shanti responded that, "*certain words from the native language may be used as part of the non-standard English that the ELLs speak.*" However, she mentioned that when ELLs have difficulty in articulating ideas, they think of a sentence in their native language and translate it into English, which could result in a "*lost in translation*" situation. Shanti recommended that teachers identify these issues and overcome these problems.

Another group, in their own thread, also raised the issue of "*lost in translation*" and the importance of using native languages in classrooms. For example, Melanie, a teacher and a native speaker of English, noticed that that her students simply don't understand a word/phrase because the rules and conventions are different in their native languages, which causes confusion.

Different cultural patterns of interaction. Participants also mentioned how cultural patterns can impact interactions in the classroom. Lena, a second year Master's student in ELL who learned English when she moved to the United States from Russia, discussed her own cross-cultural experiences as a teacher aide at a U.S. elementary school. She noted that discourse patterns differ between cultures, and some cultural interaction patterns can limit the involvement of ELLs in mainstream classrooms. However, Lena noted that, "*the curriculum doesn't allow teachers to have extra time to create and implement meaningful learning experiences that tailor to particular students and their culture.*" Sangheon, who is originally from South Korea and moved to the United States in 2005 to complete her Ph.D. in English as a Second Language, replied to Lena:

> *You brought the important issue at the end. I believe the flexibility in the curriculum is very important. In order to develop the flexible curriculum, a teacher should be prepared to differentiate the curriculum into the individual's different needs, ability, interest, and starting point. However, as a former teacher, in reality, the differentiated curriculum is very hard to be developed and realized. ELL students are kind of exceptional students and they are not the average students in the class.*

Others reported ELLs encountering many challenges in language development due to cultural differences. They pointed out that these challenges could impact ELLs' second language development, but it depends on the number of years they have been exposed to English in their home countries and the structure of their native languages. Finally, they mentioned that teachers need to create an interactive learning environment in order to engage ELLs in meaningful learning through creative methods.

Personal experiences as and with ELLs. In addition to sharing cross-cultural views, some participants reflected on the discussions from their own ELL experiences. For example, Shanti discussed the ways in which she learned English:

> *To learn more vocabulary, I will provide my own example. Being an ELL myself, my English vocabulary was not as exhaustive as a native speaker's. However, I discovered this book called "Word Power Made Easy" by Norman Lewis (2007). Not only did I learn vocabulary, but Lewis actually made it fun and almost without effort. Why was this? The book explains the roots of each word, its etymology and effortlessly engages you in learning. Such tools must be made available to teachers so that they can assist ELLs to UNDERSTAND newer words.*

In addition to learning vocabulary, Shanti shared her experience as an ELL and how she dealt with different forms of English. She noted:

> *As English language is spoken differently among different groups of people and different geographic areas, it becomes difficult for the high school ELLs to understand the American Standard English. Relating this to my experience when I was in India, I spoke "cashier" for "teller," "flat" for "apartment," "tap" for "faucet" as I was taught "British English" and not the "American Standard English." When children who speak nonstandard American English read a text in Standard English, they might translate the texts into their dialect/language for example, a child might say, "They be going' to school," instead of "They are going to school."*

Several participants responded to Shanti and discussed their own experiences as ELLs learning British English in their home countries. For example, Marina pointed out that in her country, Russia, and in Europe students are typically taught "British English." She claimed that she was confronted with confusing terminology, and it took her some time to get used to lexicon variations in the United States. Dazhi, another ELL, also replied to Shanti saying that children were taught "British English" in Shanghai, China, as well. Dazhi continued arguing that she was not sure why China and some European countries use "British English" as the Standard English for language teaching because it did cause confusion and difficulty for her and for others.

Zarina, a third-year Ph.D. student, taught English as a second language to Spanish speakers for three years. Zarina is an ELL and moved to the United States from Puerto Rico to complete her Ph.D. She discussed strategies for teaching the passive voice to ELLs. She noted that there is not "a *quick way to get ELLs to use passive voice successfully,* even though "*it is the preferred language choice for some textbooks.*" Zarina also discussed her experience teaching the passive voice:

> *Taking an SFL [systemic functional linguistic] perspective I believe the instruction will be less grammar oriented and more "meaning" oriented. Perhaps having ELLs closely observe the "theme" [subject/point of departure] of a sentence, the process this theme is "doing" and testing whether those elements match with the meaning the writer is trying to achieve in the "rheme"/object. I know that I could do this with Spanish speaking ELLs relying on translating the meaning of the sentences in their L1 but I am not sure if I can do it otherwise.*

In her reply to Zarina, Dazhi said:

> *Thanks for sharing your opinion with me! I agree with you that there is not a quick way to help ELLs master passive voice immediately, and passive voice is not advocated in academic English writing (my advisor especially pointed that out during a seminar). As for what you said about more meaning oriented than grammar oriented, I think it makes great sense to me because that is how I learned passive voice in middle school. I do not have any better suggestion right now, and sometimes I think that maybe some drill-and-practice exercises on passive voice would be helpful since such practice is a kind of reinforcement on ELLs' understanding of passive voice, but I might be wrong.*

The theme "learning issues related to ELLs" reflects a range of ways in which students in this course discussed key points in online discussions. Candidates discussed the influence of culture in ELLs' literacy development, how cultural patterns can impact interactions in the classroom, and their own experiences *as* and *with* ELLs. Next we present the theme "teaching issues related to ELLs."

Teaching Issues Related to ELLs

Academic language versus conversational language. Teachers and teacher candidates discussed ways in which academic language differs from conversational language and how these differences may influence the focus on academic and conversational language in teaching ELLs. For example, participants discussed a question related to the bigger societal issues that underlie the value that schooling ascribes to academic language versus everyday forms of communication. Sangheon noted, "*I believe both academic language and every day forms of communication should be evenly emphasized.*" She also discussed the need, especially for adolescents, to develop conversational language because of its importance to their social-emotional development. To answer the same question, several participants discussed ways to develop conversational language including using the language of pop culture or commercials to give youth and adolescents the language tools to deconstruct the language they use and repeat. Maria, a second-year Ph.D. student in Language & Literacy who focuses on Latino students' pathways to higher education, started a conversation about the importance of using the language of pop culture to help students' language and literacy development. In her initial post, Maria made important points about using cross-modal associations to guide further analysis of language in pop culture while wondering whether young people fully understand the idiomatic expressions they use and if they know how to deconstruct and analyze the messages they are *"consuming."* The topic of pop culture occurred in other threads when participants answered a question regarding the possible and appropriate interventions that classroom teachers may use. For example, Dazhi brought up an example from her life when she watched American pop culture on TV to understand vocabulary and expressions in American English.

Alina, another student who focuses on ELL, initiated a discussion about using TV commercials to develop semantic knowledge. By replying to Alina, Lena continued the discussion of encountering interesting ways of providing adolescent students with learning materials. Referring back to the main course textbook, she highlighted the idea of using advertisements to engage adolescents since many of them enjoy watching TV. As the textbook suggested, the teacher can help students identify examples of various kinds of metaphors, similes, and idioms in ads.

Participants also spoke of the ways that academic language is used in different content areas to construct disciplinary knowledge. Lena discussed the connection between academic language

and prior knowledge in the content areas. She referred to challenges to ELLs in understanding academic language in different content areas, in particular, to ELLs who don't have prior knowledge in content areas like biology or math. She pointed out that ELLs from countries with poor higher education system are not well prepared in content areas. In her replies to Lena, Irene, a second-year Ph.D. student in English Education who is originally from Puerto Rico and taught English to ELLs in Puerto Rico in both private and public universities, also supported Lena's arguments regarding consideration of ELLs' needs in content area language. She noted that reconsideration of these needs, such as understanding specialized vocabulary and unpacking complex syntactic conventions could help navigate literacy across the curriculum and in *"myriad environments."* Alina continued the discussion of ways to help ELLs understand academic language when she replied to Lena, *"Teachers can start connecting classroom content objectives to students' prior knowledge. This also helps develop ELLs' critical thinking by connecting knowledge to real world situations."* She discussed how assessment of students' prior educational, cultural, and social background can help teachers create activities based on the Vygotsky's (1978) Zone of Proximal Development (ZPD).

Teaching methodology, strategies, and techniques. Teachers and teacher candidates discussed different ways of effectively teaching ELLs while reflecting on the weekly readings and questions. When they read the story of a teacher at a middle school, they shared their views on the ways the teacher used different strategies. For example, they thought that in addition to using writing conferences and peer responses to stimulate reading and writing interest in ELLs, guest speakers could be one of the best ways of involving students in real-life situations to incorporate meaning into learning. They mentioned other effective strategies such as additional teaching resources to provide the student with more help and teaching decoding strategies that would help them transfer their first language literacy skills to their second language. Others discussed teaching in kind and encouraging ways as well as celebrating each success and building a safe classroom environment as major points in successfully teaching ELLs. In addition, Kimberly, a teacher, shared her perspective on a specific strategy:

> *When students "talk and think" about how they read and write, the teacher has an opportunity to highlight useful strategies for learning—and reinforce them daily—for greater comprehension. By focusing on giving students strategies and providing lots of comprehensible input (through exploring vocabulary and alternate meanings of words), the teacher can assist the student to succeed. Then, each success should be celebrated and built upon in a very conscious way.*

Stephanie, another teacher, in her reply to Kimberly, noted:

> *I agree with what you said about having students "talk and think" about how they read and write. I do this all the time with my students during our writer's workshop time and our literacy block time. I always have post-it notes available for the students to write down their thinking while they are reading! I am also always asking them questions about what they are writing and to explain to me why they are writing it. I agree that this goes along with what Menyuk and Brisk state. While I am completing these items with my students I am also taking notes on what I find out to further my instruction for each student the next time I meet with them. I also try to set up goals for my students to keep them motivated and try to reach a certain goal by a certain date.*

One discussion question about teaching high school ELLs asked participants to reflect on the best strategies in the course textbook. They talked about how different strategies could or have worked in real classroom contexts. Anna, a Spanish teacher at a local high school, in addition to discussing the strategies, made connections to her current content area, Spanish. She noted that one of the strategies could be of particular help to her class:

> *I especially like the pro and con list idea of comparing cultures and social issues. This idea can really help with the self-esteem of the ELL student. They can provide a perspective that no other student can, even if they were born here. The cultural and social ideas of other cultures can be very different and this can help children to view things from another person's perspective.*

Betty, a teacher, responded,

> *Anna, I agree with your statements concerning the use of pro and con idea of comparing cultures and social issues. Truly, ELL students do bring a varied perspective to the classroom discussion as they all come from such varied backgrounds and have quite different perspectives on religion, political views, as well as male and female rights and abilities. I have had some almost heated discussions between students EL as well as regular English students concerning the abilities and rights of women in the classroom. Many of these discussions stem from the students' perspectives on women's rights from their cultural viewpoints. It is good for them to discuss these issues and the students feel free to do so in their small group discussions as well as their class presentations. Many times this may turn into a debate even though it was not meant to be that type of lesson. The students learn from listening to other student's viewpoints and broaden their own thinking in the process.*

Another student, Marina, spoke of the importance of vocabulary development for ELLs:

> *As Menuyk and Brisk (2005) pointed out "Vocabulary knowledge is crucial to understanding both spoken and written language, and that knowledge should be expanded by adding items that are causing difficulties" (p.181). The authors suggested the following intervention methods: explicit instructions, reformulation strategy (analyzing television commercials), analyzing vocabulary through the written text in various areas of study and through various genres, listing of items that can create difficulties and using them frequently (finding the meaning of these items in the dictionaries, followed by discussion). Another approach suggested by Menuyk and Brisk (2005) is developing lexical comprehension through analyzing some rare words, such as using examples of figurative language in the reading assignments (metaphors, similes, and idiom).*

Vocabulary strategies were identified by others as being a crucial aspect of teaching ELLs and a necessary focus when ELLs have reading difficulties. Also related to reading, Zarina spoke of the need to focus on different genres for ELLs.

> *. . . a middle school social studies teacher had a gigantic library in her classroom. Although she preferred to share historical fiction with her students, she found it necessary to have a large array of reading levels and genres in her library. She would use these texts to explore historical events and promote ideals of empathy and understanding for other people. She argued that once children had read their first nonfiction novel they would often come back looking for more books by the same author. This of course had great weight on her too, since she needed to find books that matched students' reading interest, reading level, curricular content, and explored similar topics in different formats. Albeit demanding, her reading, writing, and kinesthetic interventions, which included journals, book reports, and dramatization made the history content engaging and approachable to her students. She does make the disclaimer that most of the children were White and middle class but I dare to say that such instructional strategies could also be used to get ELLs to tackle social studies content and its linguistic peculiarities.*

Assessment and evaluation of ELLs. Teachers and teacher candidates discussed ways in which assessment and evaluation play a role in teaching ELLs. They also discussed how assessment should always focus on students' progress, evaluate students' achievements and pinpoint areas that need to be improved. For example, Alina connects this particular point to her experiences with assessment in her classes:

> *One of the options that I tried is to create "home-made assessment forms" to monitor language development of the students, in particular new ELL students. Teachers can use the methodology offered by Menyuk and Brisk—the knowledge of language structure, pragmatics, academic language development, reading, writing necessary to succeed in school—to create student-tailored testing based on the classroom composition. Of course, this suggestion adds extra workload on the teachers' busy schedule. But it worked for me.*

In her reply to Alina, Sangheon talked about the relationship between language proficiency and ELLs' performance on assessments:

> *Usually, ELL students start with low language proficiency, so it would be hard for them to perform 100% well in academic areas, even though they show a good performance in their first language. Therefore, if they are assessed in a same way with other regular students, that's really unfair. ELL students should be treated and assessed in a different standard, at least until they have enough time to get compatible language proficiency.*

Similar to Sangheon and Alina, the cohort of teachers from one of the schools in Indiana also discussed the assessment and evaluation of ELLs. Ann, a teacher from the cohort, said:

> *Schools need to have high expectations for their ELL students. Often teachers and schools lower the expectations for ELL students because they don't think the students can complete the same task an English speaking student could. Rather than create interventions and adapt assignment to help the student they lower the expectations.*

Melanie, another teacher, in her response to Ann, stated:

> *So I agree with you—our attitude and our expectations play a huge role in student success and motivation. I agree that we need to keep those expectations high and encourage our students to rise to the challenge—differentiating along the way. As Menyuk and Brisk stated, "The vocabulary is the major obstacle for L2 learners who could be quite capable of solving the problem otherwise" (pg. 170). I notice this with my students often—it is a simple word/vocabulary issue that gets in the way! But...by knowing our students and working with them, we can help bust through that obstacle and help them succeed.*

Overall, participants identified and discussed some major issues related to ELLs' language and literacy development. They shared personal experiences as ELLs in the United States when they discussed cultural issues, interaction patterns, and the role of home languages in their own language development. Participants also discussed teaching methodology, strategies, techniques, assessment, and evaluation of ELLs.

Ways Teachers and Teacher Candidates Discussed Key Issues

As participants worked in four different groups, they discussed different questions and they did not see other groups' discussions. Only at the end of the semester did the instructor open the online discussions for everyone where they discussed what readings they liked more and what they learned from the course. The weekly questions were formulated based on the weekly readings. Then, based on the answers to the weekly questions, they usually discussed the most important or the most interesting issues when they replied to each other. In this course, 50% of the discussions addressed teaching issues related to ELLs. However, other key issues such as cultures, home languages, and/or personal experiences as or with ELLs were included in the discussions. The key issues were addressed when someone initiated the topic while responding to others, but all the key issues were consistent throughout all the online discussions during the semester. For example, the question about teaching high school ELLs that asked participants to reflect on the best strategies in the course textbook initiated the following topics: *experiential factors, intervention for history texts, and reading intervention methods.* When students did not seem to understand a question or misunderstood specific concepts, the instructor or the teaching assistant intervened to clarify or provide explanations for topics that were not clear. This was done in the form of a response to an online discussion. For example, when the ELLs in the group drew on their experiences as ELLs to make generalizations about ELLs as children developing English, the instructor or teaching assistant discussed how the processes for English language development differed for children in an English as a second language context and for adults in a foreign language context.

DISCUSSION AND CONCLUSION

This study found evidence that teachers and teacher candidates facilitated online discussions in which participants were actively encouraged to discuss and debate pertinent social, educational, and cultural issues that can affect the development of their knowledge about English language learning (Dennen & Wieland, 2007; Gunawardena et al., 1997; Zingaro & Oztok, 2012). Participants who enrolled in the online course "English Language Development" through the English Language Learning (ELL) Licensure Program discussed key issues about the language and literacy development of ELLs including learning and teaching ELLs. The outcomes met course expectations, as they learned that teaching the content areas to ELLs is a complex endeavor (Lucas et al., 2008; Schleppegrell, 2004). Participants also learned to address how language works, to focus on reading comprehension, and to critically evaluate the texts they assign to ELLs. We found evidence that experienced teachers had a better understanding of ELLs' literacy and language development in online discussions and in other course requirements, such as reports of case studies conducted at the beginning, middle, and end of the semester. Those without experience working with ELLs seemed to develop the most understanding about literacy and language development, based on the online discussions and other coursework. Participants who were ELLs seemed to learn as much as those who were non-ELLs. Non-ELLs benefited from having ELLs in their online discussion groups as they learned about their experiences as learners of the English language.

When participants discussed the learning of ELLs, they reported the influence of cultures and home languages, different cultural patterns of interaction, and personal experiences *as* and *with* ELLs. Teaching methodology, strategies, and techniques, as well as assessment and evaluation of ELLs, and academic language versus conversational language were reported when they discussed teaching ELLs. Our findings are similar to previous studies that yielded evidence that asynchronous online discussions can help teachers and teacher candidates construct their own knowledge about the literacy development of ELLs (De Wever et al., 2010; Garrison et al., 2001; Hew & Cheung, 2010; Klisc et al., 2010). Moreover, we found evidence that discussion facilitation enhanced the levels of teachers and teacher candidates' understanding of the literacy development of ELLs (Klisc et al., 2012; Means et al., 2010; Moore, 2007; Romiszowski & Mason, 2004). The participants in asynchronous online discussions tended to engage in a constructive dialogue with their classmates when online discussion was based on peer-to-peer relationships in the form of student-facilitated online discussions (Dennen & Wieland, 2007; Zingaro & Oztok, 2012). This is directly connected to the pedagogical goals described for this course.

The pedagogical goals of the course were met in the following ways. Candidates discussed the significant changes in language knowledge and use that occur in ELLs at each stage of language development, the connections to culture and the best educational practices for ELLs. For example, online discussions helped participants without experience teaching ELLs understand what types of strategies could be used for ELLs. They usually shared their appreciation and asked questions to clarify how different strategies could affect language development and ELLs' overall learning process. Similarly, participants who were non-native speakers of English shared their own experiences of what usually helped them in second language development. Their examples and recommendations helped participants who were native speakers of English gain an in-depth understanding of how ELLs feel in classrooms when they participate in learning activities. The online discussions also helped participants to consider the differences between learning English as children and as adults by reflecting on the experiences of their online colleagues who were ELLs.

Our study has some limitations. First, even though the sample represents participants' varying cultural, linguistic and professional backgrounds, the sample was not random. The participants were chosen from only one online course, and this can make the application of study findings in other online courses difficult. Second, some participants in this study did not have experience teaching ELLs, and they had to reflect on the weekly questions using examples from the literature, not from their own experiences. Nevertheless, interacting with in-service educators who teach ELLs helped them become aware of the key issues in the literacy development of ELLs.

The results of this study show that preparing content area teachers and graduate students to address the English language development needs of ELLs is a complex task. Understanding the literacy needs of ELLs is particularly significant because the English language is a medium of instruction in content area classrooms. Teachers and teacher candidates in this study, through their online discussions, have shown that they learned about strategies and techniques for second language development, differences between everyday and academic languages, and the importance of assessment and evaluation in the teaching of ELLs.

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A Study Comparing Virtual Manipulatives with Other Instructional Treatments in Third- and Fourth-Grade Classrooms

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ABSTRACT

The study reported here examined virtual manipulatives as an instructional treatment in 17 third- and fourth-grade classrooms. Students were randomly assigned to two treatment groups: texts and physical manipulatives (PM), and virtual manipulatives (VM). Results revealed no significant differences in achievement between the treatments. Additional results showed that objective ability predicted fraction achievement; virtual manipulative use can be modulated by test question type (e.g., symbolic vs. pictorial); percentage of class time using representations differed between VM and PM classrooms; and percentage of class time spent using representation types differed, potentially providing differential opportunities to learn.

INTRODUCTION

For the past 25 years, the use of technology (e.g., computers, iPads) has grown steadily in school mathematics classrooms. Technology has advanced from supporting simple programs to providing elaborate and sophisticated applications integrated with the Internet. Teachers regularly use virtual manipulatives for teaching mathematics in their classrooms using modalities that are mouse-driven for the PC, or that are manipulated on touch-screen devices. In some classrooms, the use of virtual manipulatives has replaced the use of physical manipulatives for mathematics instruction. Over the same period of time, educators and some parents have asked the question: Which is better—physical or virtual manipulatives? This is a complex question with complex answers.

Recently, two meta-analyses of research on manipulatives have been published. The first, conducted by Carbonneau, Marley, and Selig (2013), focused on the efficacy of teaching mathematics with physical (or concrete) manipulatives. The second, conducted by Moyer-Packenham & Westenskow (2012), focused on the effects of virtual manipulatives on student achievement. In their study, Carbonneau and colleagues identified 55 studies in which instruction with physical manipulatives was compared to instruction with abstract mathematical symbols. Results indicated that there were small to moderate effect sizes in favor of the use of the physical manipulatives and moderate to large effects of the manipulatives on retention. These results affirmed and extended the findings of Sowell (1989) who conducted the first meta-analysis on the effectiveness of physical manipulatives almost 25 years ago.

Moyer-Packenham and Westenskow (2012) identified 32 studies with 82 effect size scores for their meta-analysis, which examined research on instruction with virtual manipulatives compared to a variety of instructional treatments (e.g., instruction with physical manipulatives, instruction with abstract mathematics symbols, instruction with a combination of both physical and virtual manipulatives). Similar to Carbonneau et al. (2013), Moyer-Packenham and Westenskow found small to moderate effect sizes in favor of the use of the virtual manipulatives when compared with other instructional treatments. These meta-analyses provide support for some of the claims of the effectiveness of manipulative use for mathematics instruction.

While the meta-analyses conducted by Carbonneau et al. (2013) and Moyer-Packenham and Westenskow (2012) provide some insights on this question, they also reveal gaps in the research literature on physical and virtual manipulatives.

One gap is a lack of reported studies comparing physical and virtual manipulatives that include multiple elements of rigor in the methodology and research design. Previous studies comparing instruction using physical and virtual manipulatives have included some rigorous design elements, but have not included multiple elements of a rigorous experimental or quasi-experimental design. For example, only eight studies in the meta-analyses described above included random assignment of students to treatment groups when comparing physical and virtual manipulatives; only four studies included a large sample size (i.e., over 200 participants); only two studies examined the delayed effects of the treatment (i.e., delayed post testing); no studies included clear measures to assess the instructional fidelity of the treatments; and, no studies reported the psychometric properties of the instruments used. To truly understand the effects of physical and virtual manipulatives as instructional treatments in mathematics, a study that includes all these elements of a rigorous design is needed.

The purpose of the research that is the focus of this article was to address the need for a current and rigorous design in the study of physical and virtual manipulatives as instructional treatments in mathematics by incorporating multiple elements that have been absent, or not combined, in prior research. For this study, we adopted Moyer, Bolyard, and Spikell's (2002) definition of a virtual manipulative: "an interactive, web-based visual representation of a dynamic object that presents opportunities for constructing mathematical knowledge" (p. 373).

This study of physical and virtual manipulatives as instructional treatments in mathematics in 17 third- and fourth-grade classrooms randomly assigned students to the two treatments during

fraction instruction, developed instruments to assess student learning using Item Response Theory (IRT), observed instruction to determine treatment fidelity, and assessed students on measures of learning (i.e., post-tests) and retention (i.e., delayed post-tests). Including all these important research design elements in a single study contributes important insights on the effects of physical and virtual manipulatives as instructional treatments in mathematics on student achievement.

RESEARCH QUESTIONS

The overarching research question was: Are there differences in achievement on fraction learning and retention between third- and fourth-grade classrooms using virtual manipulatives fraction applets in a computer lab (VM) and those using texts and physical (concrete) manipulatives in a regular classroom (PM), as indicated by scores on pre-tests, post-tests, and delayed post-tests? Within the context of this broad question, we addressed the following sub-questions: a) Does student *objective ability*, based on pre-test scores in relation to the class pre-test average, predict fraction achievement, learning, and retention in either VM or PM classrooms? b) Is any impact of virtual manipulative use on students' fraction achievement modulated by mathematics *content test question type* (e.g., symbolic, pictorial, and combined)? c) Does percentage of class time spent in different *instructional configurations* (e.g., *groups* vs. *individually*) differ between VM and PM classrooms? d) Does percentage of class time spent using each type of fraction *representation* (e.g., pictorial, symbolic, manipulative type) differ between VM and PM classrooms? and e) Are there interaction effects of class time spent in different instructional configurations by fraction representation?

REVIEW OF THE LITERATURE

The Foundations of the Research on Manipulatives

The use of manipulatives (first physical manipulatives, now virtual manipulatives) has a long historical trajectory leading to their prevalence and use in mathematics classrooms today. The research has a 40-year history (Fuson & Briars, 1990; Moyer, 2001; Moyer & Jones, 2004; Parham, 1983; Prigge, 1978; Raphael & Wahlstrom, 1989; Sowell, 1989; Suydam, 1985; Suydam & Higgins, 1977; Thompson, 1992; Uribe-Florez & Wilkins, 2010). Studies of virtual manipulatives began over 25 years ago with the first computer-based manipulatives (Berlin & White, 1986; Clements & Battista, 1989; Clements & Sarama, 2007; Moreno & Mayer, 1999; Moyer-Packenham & Westenskow, 2012; Reimer & Moyer, 2005; Thompson, 1985).

Foundational theories on mathematics learning have led to the prevalence of manipulatives (both physical and virtual) for mathematics instruction. Over 50 years ago, Piaget's (1952) findings of clinical interviews suggested that children need experiences with the physical manipulation of objects to support their learning of abstract mathematical ideas. Bruner (1960, 1986) proposed that students' understanding occurred in three stages, the first stage an enactive stage where students interact with objects (i.e., mathematics manipulatives), prior to the iconic and symbolic stages. Zoltan Dienes (1969) suggested that students need multiple embodiments of a concept, and Dienes Blocks (a physical manipulative set of blocks) were developed for students to manipulate during mathematics experiences to promote learning.

Theories of cognition and the social construction of knowledge (Cobb, 1995; Vygotsky, 1978) consider manipulatives to be cognitive and cultural tools that are negotiated in the teaching and learning relationship. However, researchers have argued that the mathematics does not reside in the blocks themselves, and that manipulative use can be problematic for teaching and learning. For example, Ball (1992) argues, "Although kinesthetic experience can enhance perception and thinking, understanding does not travel through the fingertips and up the arm" (p. 47). Additionally, Meira's (1998) research suggested a caution to teachers that manipulatives, which are only the manufacturer's representation of a mathematical concept, have different degrees of transparency. Meira defined transparency as "an index of access to knowledge and activities rather than as an inherent feature of objects...a process mediated by unfolding activities and users' participation in ongoing sociocultural practices" (p. 121). Therefore, the physicality of the objects does not carry mathematical meaning. Meaning can only be constructed when students reflect on their actions with the manipulatives (whether physical or virtual). Additionally, recent studies on the use of manipulatives by K–8 teachers show that grade level and teacher beliefs and experience with the manipulatives are important predictors of how effectively teachers use them with students during mathematics instruction (Moyer-Packenham, Salkind, Bolyard, & Suh, 2013; Uribe-Florez & Wilkins, 2010).

In the recently adopted *Common Core State Standards for Mathematics* (CCSSM, National Governors Association Center for Best Practices—NGACBP & Council of Chief State School Officers—CCSSO, 2010) eight Mathematical Practices are described, including the expectation that students use appropriate tools strategically. Tool use includes both physical and virtual tools (i.e., physical and virtual manipulatives). Constructivist theorists suggest that learning is mediated by tools and therefore, the "tool changes the form, structure, and character of the activity" (Duffy & Cunningham, 1996, p. 19). Hiebert et al. (1997) suggest that ". . . different tools are different forms of representation, and each conveys a somewhat different message, and each emphasizes somewhat different features of the idea" (p. 58). If the CCSSM require students to "use appropriate tools" and to use those tools "strategically," it will be important for teachers to understand how students select tools for their own use when given the opportunity (Moyer & Jones, 2004) and how students employ tools to strategically solve problems (Schoenfeld, 1983).

Research using microgenetic analysis of students' problem solving has revealed that students who have a deep understanding of the relationships among different representations are able to use this knowledge in unfamiliar mathematical situations, while those

without this knowledge resist a change in their conceptual structures because their misconceptions are deeply rooted and robust (Schoenfeld, Smith, & Arcavi, 1993). Although early research using microgenetic analysis to examine students' translation among representations (e.g., graphical, symbolic, and abstract) began with students using paper and pencil, technology tools (like virtual manipulatives) can also be a source for examining students' translation among representations. As Lesh and Doerr (2003) suggest, ". . . these new conceptual tools are more than simply new ways to carry out old procedures; they are radically expanding the kind of problem solving and decision-making situations that should be emphasized in instruction and assessment" (p. 15). Technology tools like virtual manipulatives allow students to visualize, experiment, observe, reorganize, design, construct, and obtain feedback, and these actions extend students' experiences with representations beyond paper and pencil (Arcavi & Hadas, 2000). Both representational fluency (Zbiek, Heid, Blume, & Dick, 2007) and representational systems (Goldin, 2003) are important in the construction of mathematical meaning and sense making.

Design Methods Used in Previous Research on Manipulatives

Our review identified 21 peer-reviewed articles and 11 dissertations/theses that used quantitative methods to compare the effects on student achievement when virtual manipulatives were compared with other instructional treatments. As reported in the meta-analysis by Moyer-Packenham and Westenskow (2012), and of interest to the present study, were effects that focused on fraction instruction in third and fourth grade. Moyer-Packenham and Westenskow reported moderate effects for virtual manipulatives when compared with other instructional treatments in studies of fraction instruction ($f = 0.53$) and those conducted in third and fourth grade ($f = 0.37$). Also of interest were five elements that we considered to be important to a rigorous design: 1) random assignment of students to treatment groups, 2) large numbers of participants (i.e., > 200), 3) delayed post-testing to determine long-term retention effects, 4) assessment of the instructional fidelity of the treatments, and 5) the use of IRT to develop assessments specific to the study.

Among the 32 studies, many employed random assignment of intact classrooms to treatment groups, but only 10 studies randomly assigned individual students to treatment groups (Berlin & White, 1986; Burns & Hamm, 2011; Clements & Battista, 1989; Dinardi-Besterman, 1992; Hauptman, 2010; Martin & Lukong, 2005; Mendiburo & Hasselbring, 2011; Nute, 1997; Smith, 2006; Steen, Brooks, & Lyon, 2006). Of these ten studies with true random assignment, only one included a large number of participants over 200 students (Nute, 1997). Small numbers of participants could have affected the results as a confound given the differences in the pre-treatment ability levels of the groups.

Four studies had more than 200 participants (Clements, Battista, & Sarama, 2001; Nute, 1997; Pleet, 1991; Terry, 1995). Of these, three were dissertations, and there was no evidence that they were then published in peer-reviewed journals. The study with the largest number of participants (1,055) examined the use of Logo Geometry software (Clements, Battista, & Sarama, 2001). The other studies ranged from 241 to 560 participants. All four studies were conducted over 10 years ago and used either researcher-designed applets or mathematics software, making these technologies different from current virtual manipulatives, which contain many unique affordances for learners.

Our review located only two studies that employed delayed post-testing to determine long-term retention effects of virtual manipulatives as a treatment (Clements, et al., 2001; Lin, 2010). Clements et al. reported that scores of the group using Logo geometry software increased significantly from the previous test to the delayed test, while the scores of students in traditional instruction decreased. Results of Lin's study showed that pre-service teachers using virtual manipulatives outperformed pre-service teachers using traditional instruction in procedural ($f = 0.15$) and conceptual ($f = 0.17$) fraction knowledge, with a significant difference on pre, post, and delayed tests following a four-week delay.

We located only six studies in which virtual manipulatives were used for instructional comparisons of fraction concept learning in elementary classrooms that included pre- and post-testing to determine statistically significant differences among the treatment groups and effect sizes (Ball, 1988; Burns & Hamm, 2011; Melideo & Dodson, 2009; Mendiburo & Hasselbring, 2011; Moyer-Packenham & Suh, 2012; Suh & Moyer-Packenham, 2007). For example, in examining the instruction of fraction addition algorithms, Ball compared the use of virtual manipulatives with traditional instructional techniques in five classes of fourth-grade students. Suh and Moyer-Packenham compared the use of physical and virtual manipulatives in the instruction of fraction addition to 36 third-grade students. In both studies, the classes that used virtual manipulatives significantly outperformed the groups that did not. However, the other four studies did not report statistically significant differences between treatment groups, although there were pre- to post-test gains for all groups. For example, Melideo and Dodson found no significant differences between groups when comparing physical and virtual manipulatives during fraction instruction with 20 fourth-grade students during a 9-day unit, and Mendiburo and Hasselbring found no significant differences between groups of fifth graders in a 10-day unit on fractions. Moyer-Packenham and Suh conducted the same type of comparison (i.e., physical vs. virtual) with 24 fifth-grade students spending 5 days using virtual manipulatives and also found no significant differences between groups. Burns & Hamm's study of 156 third- and fourth-grade students also revealed no statistically significant differences, but the treatment only lasted for one class session (i.e., 60 minutes).

The summary of research on physical and virtual manipulatives reveals a variety of limitations in research methods. Because of these limitations, confounding factors may account for the positive, negative, or neutral results that have been obtained in these studies. Our review points to the need for studies that compare

physical and virtual manipulatives and that include multiple elements of a rigorous design. The present study addresses this need by including physical and virtual manipulatives as instructional treatments, a large number of participants, random assignment of students to treatments, rigorously developed mathematics assessments, measures that assess the instructional fidelity of the treatments, and delayed post-tests to assess retention. This study makes an important contribution to the literature by combining multiple rigorous research design elements in a single study that examines physical and virtual manipulatives.

METHODOLOGY

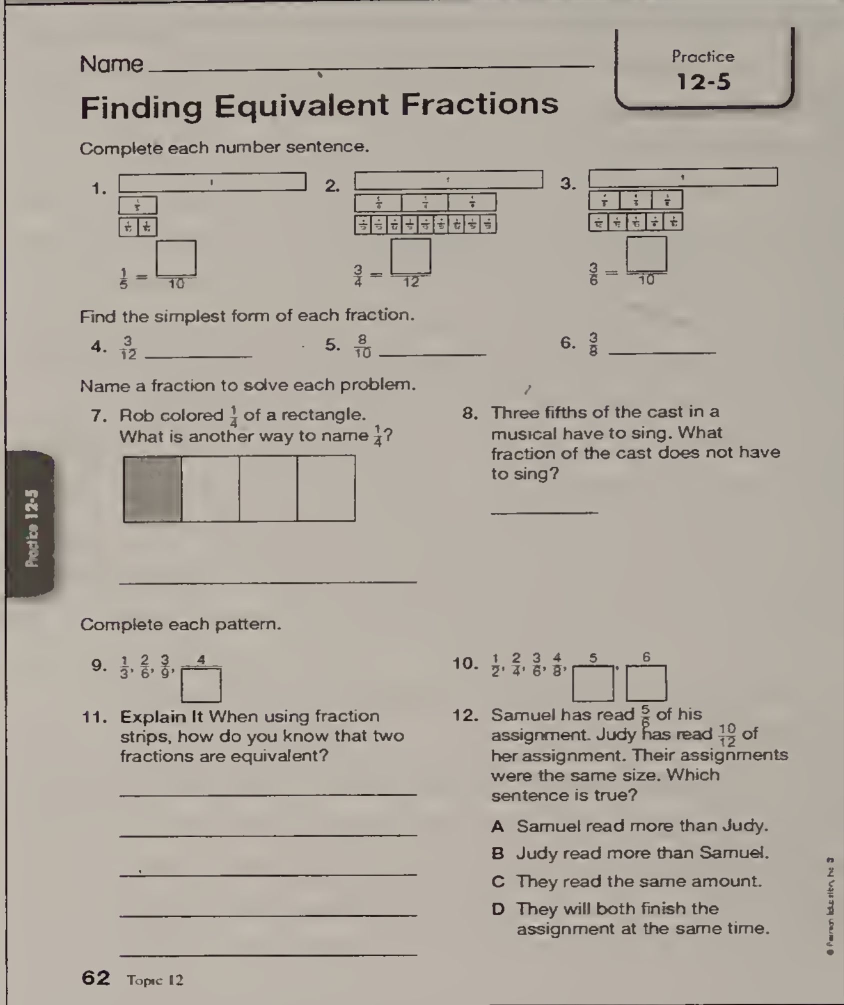
Participants

Three hundred fifty students (Third grade, N = 156; Fourth grade, N = 194) from 17 public school classrooms, located in 7 different elementary schools in 3 school districts, participated in the study. Researchers randomly assigned participants within-class to one of two treatment groups. One of the treatment groups used texts and physical manipulatives in regular classrooms (PM); the other treatment group used virtual manipulatives in a computer lab (VM).

Texts and physical manipulatives (PM) treatment group. The 17 PM classes were taught by 14 different third- and fourth-grade public school classroom teachers. The teachers' experience ranged from 3–32 years, with a mean of 17.6 years; all except two had taught third or fourth grade for three years or more. In a survey administered to the teachers, 64.3% reported that their students used *technology* every day prior to this study, while 37.7% reported that their students used technology once or twice a week. The teachers defined technology use as the SMART Board™, computers, and math programs. When asked about students' use of *computers*, 39.3% of teachers reported that their students used computers every day, while 60.7% reported their students used computers at least once or twice a week. Half of the teachers had never used the *National Library of Virtual Manipulatives (NLVM)* with their students, 14% reported using the NLVM website about twice per month, and 36% reported using it a few times a year.

During the treatment, all the classrooms used Pearson SuccessNet curriculum materials (Scott Foresman/Addison Wesley Mathematics 2005 textbook). The instructional worksheets for students provided by the publisher include pictorial models and numeric and text-based information on each worksheet. (See Figure 1.) These materials were used by the instructors in the PM groups during the study. Twelve of the 17 classrooms (70.5%) also used SMART Board™ technology during mathematics instruction to display some of these images for students during the lessons. As can be seen from the worksheet in Figure 1, the pictorial models on the student worksheet match the physical manipulatives available for students that are shown in Figure 2. When teachers used the physical manipulatives during mathematics instruction, they demonstrated what they wanted students to do with the tools in order to solve mathematics problems. In these lessons, teachers

Figure 1. Example of the Pearson SuccessNet Curriculum Materials in the Mathematics Textbook Published by Scott Foresman/Addison Wesley (2005).


Name ______ Practice 12-5

Finding Equivalent Fractions

Complete each number sentence.

1. $\frac{1}{5} = \frac{\square}{10}$ 2. $\frac{3}{4} = \frac{\square}{12}$ 3. $\frac{3}{6} = \frac{\square}{10}$

Find the simplest form of each fraction.

4. $\frac{3}{12}$ ______ 5. $\frac{8}{10}$ ______ 6. $\frac{3}{8}$ ______

Name a fraction to solve each problem.

7. Rob colored $\frac{1}{4}$ of a rectangle. What is another way to name $\frac{1}{4}$?

8. Three fifths of the cast in a musical have to sing. What fraction of the cast does not have to sing?

Complete each pattern.

9. $\frac{1}{3}, \frac{2}{6}, \frac{3}{9}, \frac{4}{\square}$ 10. $\frac{1}{2}, \frac{2}{4}, \frac{3}{6}, \frac{4}{8}, \frac{5}{\square}, \frac{6}{\square}$

11. **Explain It** When using fraction strips, how do you know that two fractions are equivalent?

12. Samuel has read $\frac{5}{6}$ of his assignment. Judy has read $\frac{10}{12}$ of her assignment. Their assignments were the same size. Which sentence is true?

A Samuel read more than Judy.
B Judy read more than Samuel.
C They read the same amount.
D They will both finish the assignment at the same time.

62 Topic 12

introduced a concept using the manipulatives. Then teachers allowed students to use the physical manipulatives (e.g., fraction pies or fraction tiles) while completing the worksheet.

The most common physical manipulatives used during fraction instruction included fraction pies and fraction tiles (see Figure 2). The fraction pies are a circular region representation of the whole divided into different numbers of fractional parts. The fraction tiles are a length model where one whole length is divided into different numbers of fractional parts. Fraction pies and fraction tiles can be used for comparison and to find equivalent portions.

Teachers also used other fraction manipulatives, worksheets, and teacher-created resources (e.g., paper cut-outs of fraction

Figure 2. Physical Manipulatives (Fraction Pies and Fraction Tiles) Used in the PM Treatment Groups.

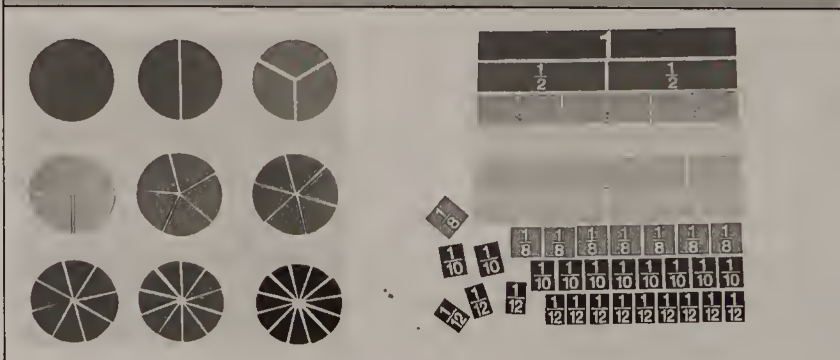
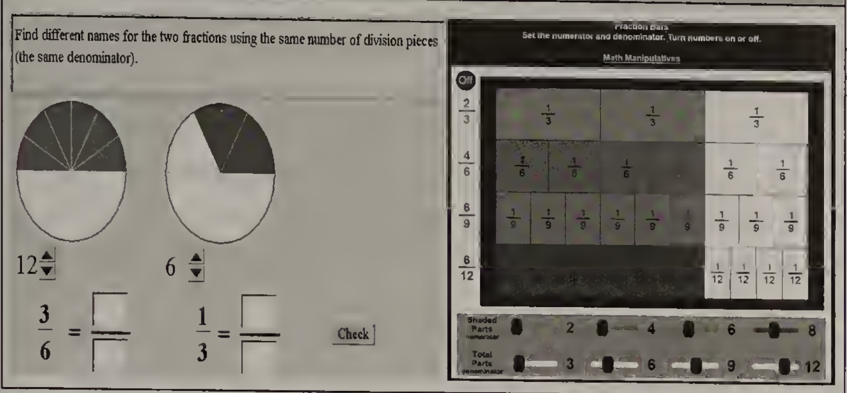


Figure 3. Virtual Manipulatives (Fraction Pies and Fraction Tiles) Used in the VM Treatment Groups.



regions) during the fraction unit. Over 43% of teachers reported that they did not use computers or computer programs during the study, 28% reported using computers—but not virtual manipulatives—and 28% used computers every day, but again, not virtual manipulatives.

Virtual manipulatives (VM) treatment group. Four individuals affiliated with the local university taught the VM groups, including three doctoral-level graduate students and one university faculty mem-

Figure 4. Example of an Instructor-developed Task Sheet, Designed for Teaching Fraction Concepts Using Virtual Manipulatives.

Name ____________________ Teacher ____________________

DIFFERENT DENOMINATORS

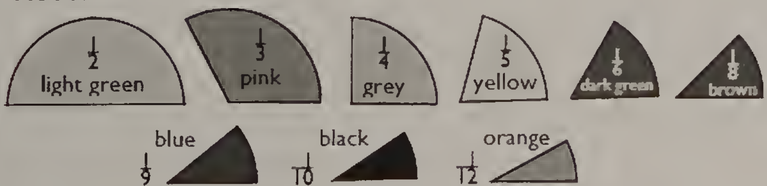
Explore

$\frac{1}{2} + \frac{1}{4} =$ $\quad$ $\frac{1}{4} + \frac{3}{8} =$ $\quad$ $\frac{2}{5} + \frac{2}{10} =$

$\frac{\ }{4} + \frac{\ }{4} =$ $\quad$ $\frac{\ }{8} + \frac{\ }{8} =$ $\quad$ $\frac{\ }{10} + \frac{\ }{10}$

What do you have to remember when adding or subtracting fractions?

Record



Use the Fraction Pieces applet to solve the following:

$\frac{5}{6} - \frac{1}{3} =$ $\quad$ $\frac{2}{5} - \frac{3}{10} =$ $\quad$ $\frac{2}{9} + \frac{2}{3} =$ $\quad$ $\frac{5}{8} - \frac{1}{4} =$

Draw a picture to help you solve the following. Label each of the parts.

$\frac{1}{2} + \frac{1}{4} =$ $\quad$ $\frac{1}{3} + \frac{2}{9} =$ $\quad$ $\frac{2}{5} + \frac{3}{10} =$

Grade 4: Adding/Subtracting Fractions with Uncommon Denominators
VM: Fraction Pieces

ber (all former elementary teachers). The university teachers' public school teaching experience ranged from 7–30 years, with a mean of 14.6 years, and three of the four had public school experience teaching third or fourth grade.

The students in the VM treatment groups used virtual manipulative fraction applets from a variety of websites. Examples of the virtual manipulative applets included virtual fraction pies and virtual fraction tiles (see Figure 3). The virtual fraction pies are a representation of a circular region and the "arrow keys" on the virtual tool allow students to divide the circular region into different numbers of fractional parts. The virtual fraction tiles are a representation of a length model. Students can use a "slider" on the virtual tool, which allows them to create different numbers of fractional parts and shade the fractional parts for comparison. On both the fraction pies and the fraction tiles, numeric information accompanies the visual models that are in the virtual manipulatives tools.

During each lesson in the VM treatment groups, the instructors began with an introduction to the mathematics concept and to the virtual manipulatives that would be used by meeting with the whole group of students. Instructors demonstrated the keys and how to navigate within each of the virtual manipulative tools. Next the students interacted with one or more of the virtual manipulative applets independently to complete mathematics tasks. These independent interactions and explorations were guided by a task sheet that was specifically designed to teach fraction concepts using virtual manipulatives. An example of one of the VM task sheets is shown in Figure 4.

During the VM lessons, the instructors moved about the computer classroom and interacted with individual students to provide guidance and feedback and facilitate students using the virtual manipulatives to complete the guided task sheets. Students worked at their individual computers and task sheets at their own pace. At the end of each lesson, teachers pulled students back together as a whole group for a summary discussion of the day's concept.

The VM instructors also used some of the Pearson SuccessNet curriculum materials that were used by the PM instructors in addition to the VM instructor-developed task sheets. Tasks specific to problem exploration using the virtual manipulatives enabled VM task sheets to mirror the mathematical content being taught to the PM group. An expert group of experienced teachers had evaluated the lesson materials to determine the mathematical content match between PM and VM lessons. In preparation for the research project, the lesson materials had been piloted in test classrooms, reviewed, and revised, as necessary.

Procedures

Student demographics of gender, race, English Language Learner (ELL) status; socio-economic status (SES); and two measures of mathematical ability, subjective and objective, were reported by each classroom teacher at the beginning of the study. *Subjective* mathematical ability was determined by teacher rating of students' mathematical ability as high, medium, or low, based on their

knowledge of students' prior mathematics performance. The research team rated students' *objective* mathematical ability by comparing each student's pre-test score to the class pre-test average and standard deviation. Standardized scores one standard deviation or more below the mean were classified as low, while scores one standard deviation or more above the mean were classified as high. The remaining scores were rated as medium. At the end of the unit on fractions, classroom teachers identified any student absent for more than 40% of the time. Subsequent data analyses did not include information about these students. Teachers reported additional data concerning factors possibly influencing the instructional environment.

The design of the study ensured instructional fidelity across PM and VM treatment groups. Before beginning instruction, each paired teacher met to specify the number of days allotted for the fraction unit and to correlate lessons with the state's mathematics curriculum. This collaboration ensured that students received instruction on the same mathematical content regardless of treatment group. In an effort to address possible teacher effects, the instructors in the PM and VM treatment groups all had a minimum of three years of teaching experience, and the mean number of years of teaching experience was similar for the two treatment groups (17.6 years for the PM group and 14.6 for the VM group). Additionally, both groups of teachers had experience teaching elementary school, with almost all of the instructors having taught in Grades 3 and 4 previously. Over 70% of the lessons were observed to ensure that there were no differences in the mathematics content that students learned during the lessons, and that the instructional materials and strategies were documented for analysis. To further ensure conformity in lesson plans between treatment groups, each set of paired teachers met after each day's lesson to discuss plans for the next day. If the teachers decided that students were struggling with a particular concept, the pair of instructors together decided to re-teach that concept. Thus, daily check-ins ensured that students in both treatment groups learned the same content each day. Finally, null statistical comparisons of learning and retention outcomes between PM and VM instruction groups further reinforces our claim that teacher effects were not likely to contribute to the significant effects reported here.

Treatment groups met daily, and all fraction instruction occurred during regularly scheduled mathematics classes. VM treatment groups spent the fraction unit in the computer lab, using individual computers for approximately 50 minutes each day. Excluding administration of pre- and post-tests to both treatment groups by the classroom teachers, the duration of the fraction unit in each of the 17 classrooms ranged from 9 to 17 days (avg. = 11 days).

Third-grade lessons addressed the following concepts: identify the denominator of a fraction as the number of equal parts of the unit whole and the numerator of a fraction as the number of equal parts being considered; define regions and sets of objects as a whole, and divide the whole into equal parts using a variety of objects, models, and illustrations; name and write a fraction to represent a portion of a unit whole for halves, thirds, fourths, sixths, and eighths; place fractions on the number line, and compare and order fractions using models, pictures, number line, and symbols; and find equivalent fractions using concrete and pictorial representations.

Fourth-grade lessons addressed the following concepts: divide regions, lengths, and sets of objects into equal parts using a variety of models and illustrations; name and write a fraction to represent a portion of a unit whole length or set for halves, thirds, fourths, fifths, sixths, eighths, and tenths; generate equivalent fractions, and simplify fractions using models, pictures, and symbols; order simple fractions; use models to add and subtract simple fractions where one single digit denominator is one, two, or three times the other; add and subtract simple fractions where one single digit denominator is one, two, or three times the other.

Instruments

Mathematics content tests and observation ethograms were used to collect data (MacNulty, Mech, & Smith, 2007). Three mathematics content tests were administered: a pre-test immediately prior to the fraction unit, a post-test the day after the conclusion of the fraction unit, and a delayed post-test administered six to eight weeks after the fraction unit concluded. Throughout the study, observation ethograms documented instruction in each classroom. The following sections describe the development and administration of these instruments.

Pre- and post-tests. For the fractions pre- and post-tests, items were taken and/or adapted from four standardized test databases: National Assessment of Educational Progress (NAEP, 2011), Massachusetts Comprehensive Assessment System (MCAS, 2011), Utah Test Item Pool Service (UTIPS, 2011), and Virginia Standards of Learning (Virginia-SOL, 2010). Questions were selected on the basis of three criteria: 1) alignment with third- and fourth-grade objectives in the state where the study was conducted; 2) representation of a range of question-type difficulties to differentiate students' scores based on fraction knowledge; and 3) incorporation of a variety of representation types including symbolic items (e.g., numerals and operations only), pictorial items (e.g., pictorial models with a written question stem), and combined items (e.g., numerals and operations combined with pictorial models with a written question stem). One form of 27 multiple-choice questions and 3 open-ended questions was compiled for fourth grade and checked for content validity by five experienced elementary school teachers with graduate degrees. In the fall of the academic year prior to the study, these items were piloted with 275 fifth-grade students from 10 elementary schools in six school districts in order to assess the item difficulties and reliability of the measure.

Item difficulties, fit statistics, reliabilities, and separation indices were estimated using BILOG-MG (Zimowski, Muraki, Mislevy, & Bock, 1996). Biserial correlations for these items were good, ranging between .334 and .776 with a mean of .579 (SD = .115), indicating that the items measured the same construct (i.e., knowledge of fourth-grade fraction concepts). The measure had a high reliability of .8837, showing that it measured knowledge of fourth-grade

fractions consistently across the sampled population. A good distribution of fraction items of different difficulty levels—necessary to differentiate knowledgeable students from less knowledgeable students—was demonstrated by the range of the item difficulties, from about one standard deviation at both ends (–1.198 to .913) with a mean of –.114 (SD = .676). Principles of item response theory were used to construct two forms roughly similar to one another in content and difficulty, but with different sets of items; this was done in order to prevent test-retest effects. All items were then placed on one form and piloted with students, thus linking the original forms to each other using common person equating. Item difficulties on all forms (pre-test, post-test, and delayed post-test) were subsequently calibrated with this entire sample. Each form contained seventeen multiple-choice items with five common linking items and two open-response items. Third-grade tests were created in the same way and piloted with groups of fourth-grade students who were not participating in the study. Procedures for developing the third-grade tests produced similar results.

Observation ethograms. Researchers documented instruction and the use of representations in all the classrooms. Three observers collectively observed 70% of the lessons using a modified ethogram protocol. Ethograms are instruments traditionally used by animal behavior researchers to accurately and efficiently describe the frequency and duration of behaviors made by a species observed in the field, without any subjective evaluation of these observed behaviors (e.g., MacNulty et al., 2007). This instrument provides a cohesive inventory of behavioral patterns describing what a particular species spends its time doing in a studied environment. Here, we used an ethogram adapted for naturalistic classroom observations of humans. At 5-minute intervals throughout the observation of a lesson, observers recorded the types of representations used by teachers and students. For example, observers recorded information on the presentation of mathematical content, terminology, mathematical procedures; use of pictorial, symbolic, physical, and virtual manipulative models; and students' access to physical manipulatives (i.e., passive group viewing or active individual manipulation). VM teachers documented their use of different types of models and students' access to virtual manipulatives via instructor logs, which were subsequently coded and converted to an ethogram protocol as well. These ethograms, in sum, provided a quantitative measure of the students' exposure and access to various fraction concepts, terminology, and types of representation in each of the PM and VM treatment classrooms. These tabulated data provide the basis for the subsequent analyses described below.

RESULTS

The results that follow are organized around our main question and sub-questions. We first present an analysis of the overall mathematics achievement results by grade level to answer the overarching question which focused on possible differences in overall achievement, learning, and retention in third- and fourth-grade VM and PM treatment classrooms. Then, we address the sub-questions, focusing on the possible mediating variables of *objective ability*, mathematics *content test question type*, time spent in different *instructional configurations*, time spent using each type of fraction *representation*, and interaction effects between instructional configurations by fraction representation.

Learning and Retention

Our overarching research question was: Are there differences in overall achievement on fraction learning and retention between third- and fourth-grade classrooms using virtual fraction applets in a computer lab (VM) and those using texts and physical manipulatives in a regular classroom (PM), as indicated by scores on the pre-test, post-test, and delayed post-tests? We calculated "learning" scores for each student by subtracting the pre-test score from the post-test 1 score. The greater the learning score, the more learning of fraction material between the pre-test and post-test 1. We next calculated a "retention" score to describe the amount of fraction material retained between post-test 1 and post-test 2. The retention variable was calculated by subtracting each student's post-test 2 score from the post-test 1 score. A negative retention score indicates that information was lost between post-tests. Pre-test, post-test 1, and post-test 2 scores for each treatment group in all third-grade classrooms are presented in Table 1 and in all fourth-grade classrooms in Table 2.

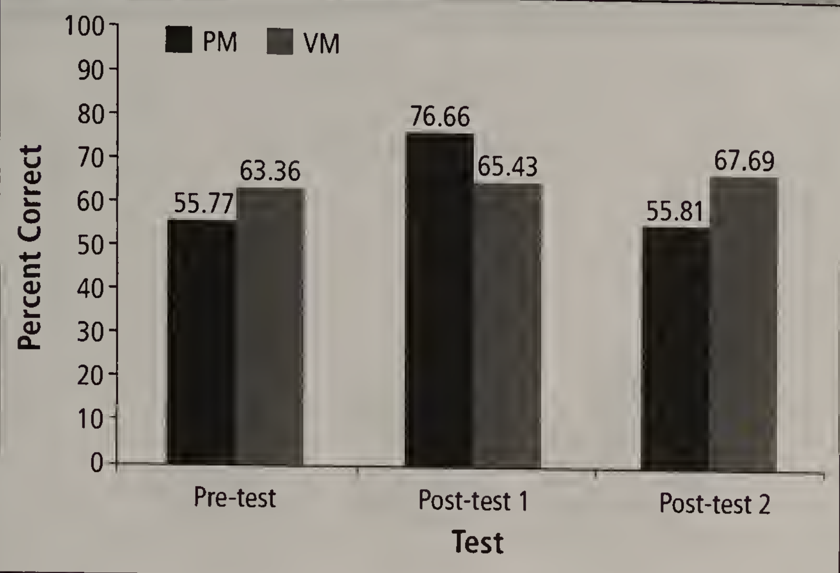
Repeated measures analysis of variance (ANOVA) were used to test the null hypothesis for third grade that any obtained differences in test scores both across time (e.g., pre-test, post-test 1, & post-test 2) and across experimental group (e.g., VM & PM) were due to chance. We identified a significant effect of test (pre-test: Mean = 60.37, SD = 20.7; Post-Test 1: Mean = 70.57, SD = 19.62; Post-Test 2: Mean = 62.12, SD = 20.36) (F(1.975, 302.133) = 8.896, MSE = 4052.169, $p < .000$, *partial* $\eta^2 = .055$), driven by a significant increase in scores from the pre-test to post-test 1 (Bonferroni $p < .001$), followed by a drop in scores from post-test 1 to post-test 2 that approached significance (Bonferroni $p = .054$). There was no difference in scores between pre-test and post-test 2 (Bonferroni $p > .05$). There was no significant difference between the average test scores in VM and PM groups (F(1, 160) = .694, MSE = 588.51, $p = .41$, *partial* $\eta^2 = .004$). Average pre-test- post-test 1, and post-test 2 scores for each treatment group in third-grade classrooms are shown in Figure 5. The main effect of time is evident in the significant rise in third-grade test scores between pre-test and post-test 1 (p < .001), and nearly significant drop in test scores between post-test 1 and post-test 2 (p = .054). While slight differences in test score averages existed between PM and VM groups within each test, these differences were not statistically significant.

An additional repeated measures ANOVA was conducted for fourth grade. Similar to the third-grade group, results identified a significant main effect of test (pre-test: Mean = 47.97, SD = 19.03; post-test 1: Mean = 65.65, SD = 21.65; post-test 2: Mean = 48.24, SD = 18.58), F(2, 364) = 100.02, MSE =

Table 1. Mean (SD) Third-Grade Students Performance: Teacher × Treatment Group × Test						
Teacher	Treatment Group	Pre-Test %	Post-Test 1 %	Post-Test 2 %	Learning Avg.	Retention Avg.
Mrs. Alpha	VM	31.81 (12.53)	72.72 (19.07)	43.94 (14.56)	40.91 (24.89)	–28.79 (23.29)
	PM	50.90 (20.93)	85.45 (8.13)	50.90 (26.19)	34.55 (19.71)	–34.55 (24.39)
Mrs. Bravo	VM	69.70 (13.63)	85.86 (8.01)	72.73 (7.87)	16.16 (13.46)	–13.13 (10.27)
	PM	71.71 (21.53)	79.80 (19.69)	61.62 (20.21)	8.10 (11.53)	–18.20 (12.02)
Mr. Charlie	VM	60.61 (18.32)	75.00 (11.05)	54.55 (15.98)	14.40 (14.22)	–20.45 (16.95)
	PM	48.95 (22.12)	74.13 (19.58)	57.34 (21.44)	25.17 (22.31)	–16.78 (16.94)
Mrs. Delta*	VM	56.06 (19.53)	59.10 (20.26)	58.57 (25.37)	3.03 (25.52)	–.51 (23.01)
	PM	58.90 (21.21)	67.99 (17.52)	56.52 (19.56)	9.10 (18.99)	–11.46 (21.27)
Mrs. Echo	VM	67.27 (19.73)	72.72 (18.68)	69.10 (18.77)	5.45 (15.56)	–3.64 (13.68)
	PM	67.27 (24.26)	75.45 (25.37)	71.81 (18.40)	14.54 (12.27)	–3.63 (23.93)
Mrs. Foxtrot	VM	63.64 (17.52)	69.32 (18.78)	72.72 (13.74)	5.68 (10.79)	3.41 (8.32)
	PM	66.94 (16.40)	78.51 (13.65)	72.72 (11.49)	11.57 (18.67)	–5.78 (11.69)
Mrs. Golf	VM	74.54 (13.41)	70.00 (10.54)	76.40 (13.68)	–4.54 (10.71)	6.36 (14.87)
	PM	58.33 (21.39)	46.97 (22.21)	54.54 (24.51)	–11.36 (15.07)	7.57 (19.31)
Total	VM	60.51 (16.38)	72.10 (15.20)	63.99 (15.71)	11.58 (16.45)	–8.10 (15.77)
	PM	59.52 (21.12)	72.61 (18.02)	60.78 (20.26)	13.09 (16.93)	–11.83 (18.51)
Note: The asterisks in Tables 1 and 2 indicate teachers who taught more than one class.						

Table 2. Fourth-Grade Students Performance: Teacher × Treatment Group × Test						
Teacher	Treatment Group	Pre-Test %	Post-Test 1 %	Post-Test 2 %	Learning Avg.	Retention Avg.
Mr. Hotel*	VM	50.98 (18.63)	61.06 (22.51)	42.85 (19.25)	10.08 (16.12)	–18.21 (17.34)
	PM	52.45 (17.93)	60.78 (19.13)	40.68 (16.63)	8.33 (17.25)	–20.09 (16.89)
Mrs. India*	VM	49.85 (20.00)	67.50 (20.93)	54.34 (14.98)	17.64 (20.46)	–13.16 (20.45)
	PM	49.41 (21.62)	69.11 (19.91)	46.47 (16.84)	19.40 (22.92)	–22.64 (16.88)
Mrs. Juliet	VM	47.05 (20.88)	67.37 (18.51)	45.45 (15.07)	20.32 (20.60)	–21.92 (13.94)
	PM	47.89 (17.39)	60.51 (23.28)	38.65 (16.65)	12.60 (15.27)	–21.84 (11.86)
Mrs. Kilo	VM	47.05 (20.65)	57.98 (19.92)	45.37 (22.19)	10.92 (12.44)	–12.60 (20.77)
	PM	43.53 (24.04)	58.82 (25.41)	40.00 (17.71)	15.29 (15.23)	–18.82 (21.79)
Mrs. Lima	VM	35.94 (16.49)	67.32 (30.86)	57.51 (22.74)	31.37 (24.07)	–9.80 (12.82)
	PM	39.57 (14.43)	69.51 (19.65)	55.08 (14.94)	29.94 (14.03)	–14.43 (11.87)
Mrs. Mike	VM	61.17 (18.84)	80.58 (25.27)	59.41 (24.08)	19.41 (17.54)	–21.17 (9.86)
	PM	50.98 (19.32)	75.49 (20.96)	64.21 (15.35)	24.50 (20.19)	–11.27 (13.35)
Mrs. November	VM	42.64 (16.47)	59.80 (20.80)	45.09 (20.42)	17.15 (23.32)	–14.70 (14.94)
	PM	41.17 (14.18)	67.64 (19.18)	51.96 (13.23)	53.47 (21.35)	–15.68 (17.25)
Total	VM	47.81 (18.58)	65.94 (23.37)	50.01 (20.04)	18.13 (19.22)	–15.94 (16.23)
	PM	46.43 (18.42)	65.98 (20.39)	48.15 (15.68)	19.55 (18.03)	–17.83 (15.20)
Note: The asterisks in Tables 1 and 2 indicate teachers who taught more than one class.						

Figure 5. Third-Grade Performance: Treatment Group × Test



16295.68, $p < .000$, *partial* $\eta^2 = .36$, indicating that the average scores differed significantly across tests. This effect was driven by a significant difference in post-test 1 scores compared to pre-test and post-test 2 (Bonferroni $p < .001$ for both comparisons). There was no difference between pre-test and post-test 2 scores (Bonferroni $p > .05$). There was no significant difference between the average test scores in VM and PM groups ($F(1, 195) = .002$, $MSE = 1.72$, $p = .95$, *partial* $\eta^2 = .00$). Average pre-test-post-test 1, and post-test 2 scores for each treatment group in fourth-grade classrooms are shown in Figure 6. The main effect of time is again evident in the significant rise in test scores between pre-test and post-test 1 ($p < .001$), and subsequent significant drop in test scores between post-test 1 and post-test 2 ($p < .001$). Again, for fourth grade the differences in test scores between PM and VM groups were not statistically significant.

Figure 6. Fourth-Grade Performance: Treatment Group × Test

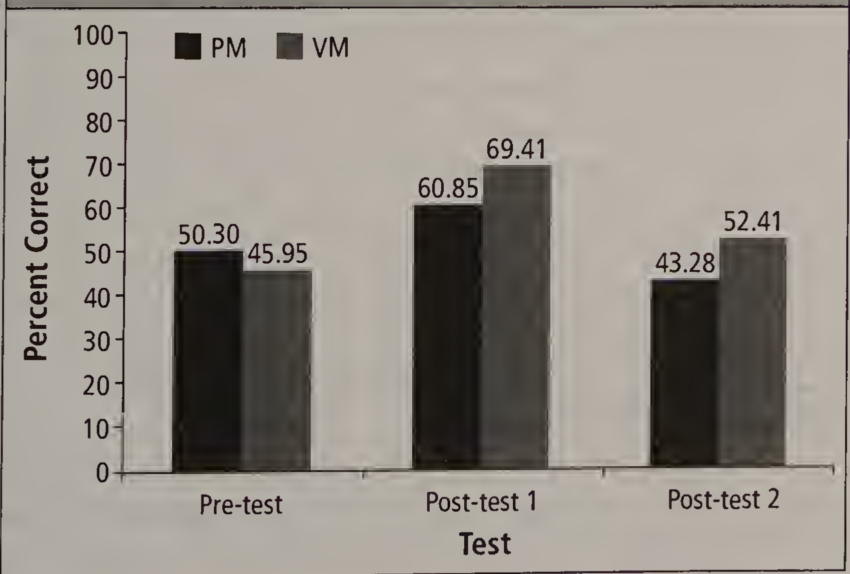
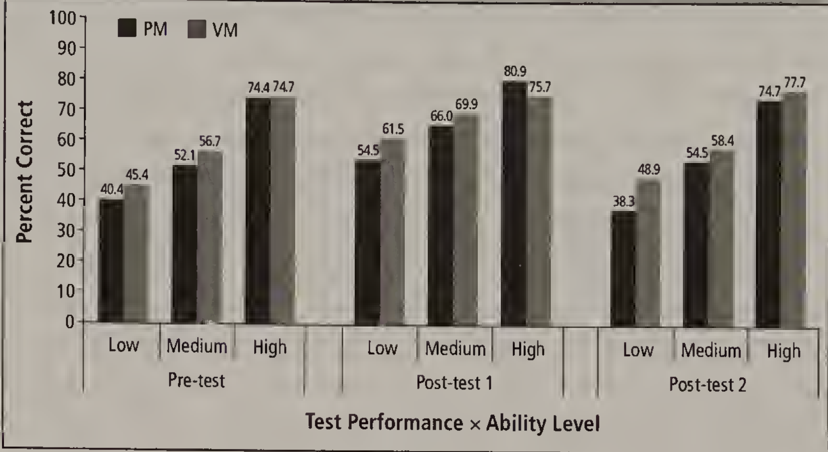


Figure 7. Third-Grade Performance: Group × Objective Ability × Test

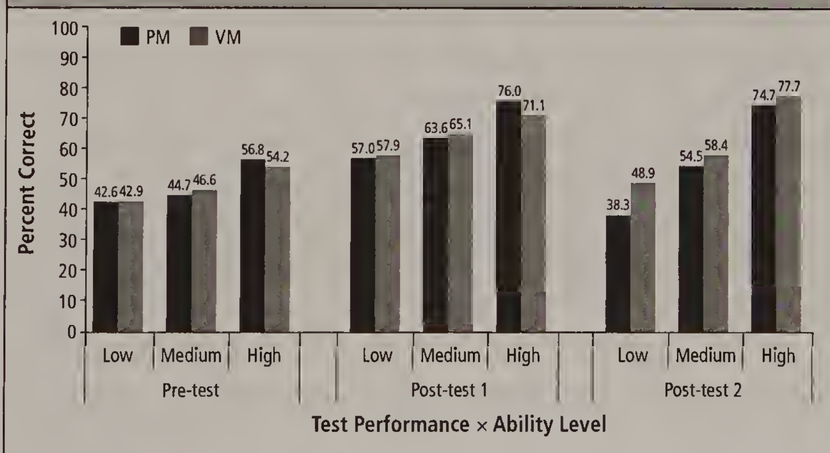


Effects of Objective Ability

Our first subquestion was: Does student *objective ability*, based on pre-test student score in relation to class pre-test average, predict fraction achievement, learning, and retention in VM or PM classrooms? In third grade, we identified a significant interaction between test and objective ability ($F(1.975, 302.133) = 6.534$, $MSE = 2976.379$, $p = .002$, partial $\eta^2 = .041$), indicating that the scores for students objectively rated as "High" (Mean = 76.39, SD = 15.49) increased more dramatically from pre-test to post-test 1 than students rated "Low" (Mean = 59.64, SD = 17.88) and "Medium" (Mean = 48.21, SD = 20.02). Additionally, objectively rated "High" students maintained higher performance from post-test 1 to post-test 2 than "Low" or "Medium" students (see Figure 7). No other comparisons were significant.

A similar analysis in fourth grade identified a significant main effect of objective ability (High: Mean = 60.75, SD = 2.09; Medium: Mean = 52.97, SD = 1.66; Low: Mean = 49.88, SD = 2.73), $F(2, 182) = 6.275$, $MSE = 4724.45$, $p = .002$, partial $\eta^2 = .065$, with significant individual comparisons between objectively rated High and Low students (Bonferroni $p = .006$), and between objectively rated High and Medium students (Bonferroni $p = .012$), but not between Medium and Low students (Bonferroni $p > .05$). No other main effects were identified (Figure 8).

Figure 8. Fourth-Grade Performance: Group × Objective Ability × Test



Effects by Content Question Type: Visual, Symbolic, and Combined

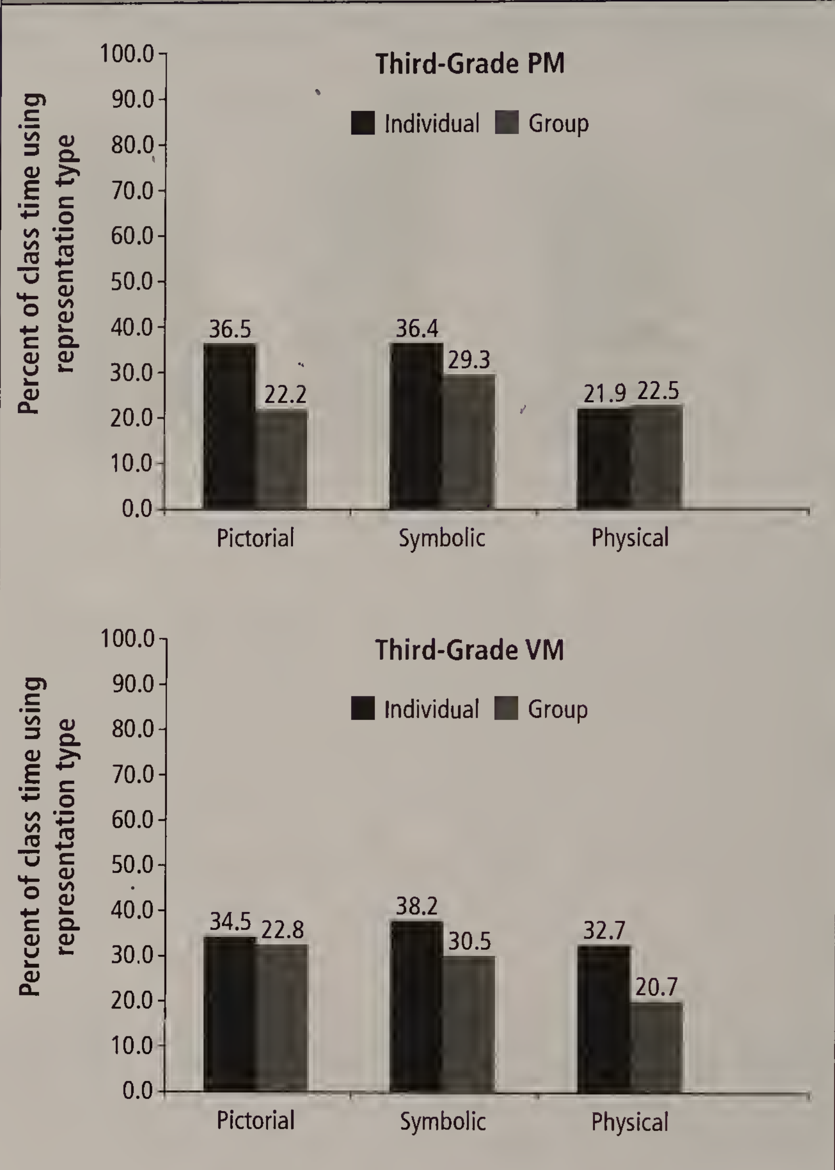
Our next sub-question was: Is any impact of virtual manipulative use on students' fraction achievement modulated by mathematics *test question type* (e.g., pictorial, symbolic, and combined)? No third-grade classroom provided purely symbolic question types, so only pictorial and combined questions types were analyzed for this sample. In third grade, post-test 1, we identified a significant main effect of question type ($F(1, 154) = 33.56$, $MSE = 10650.06$, *H-F* $p < .001$, *partial* $\eta^2 = .179$), driven by greater overall performance on combined ($\mu = 78.05$) compared to pictorial ($\mu = 66.29$) question types. This difference was not observed for post-test 2 (*H-F* $p > .05$). No other analyses showed statistically significant differences. This pattern of results indicates that combined question types revealed third-grade students' short-term learning (i.e., post-test 1) of fraction material to a greater degree than pictorial question types, but no difference was found between the two question types in terms of long-term retention.

Pictorial, symbolic, and combined questions types were analyzed for fourth grade. A similar trend as that identified in third grade emerged for fourth grade: Repeated measures ANOVA identified a significant main effect of question type ($F(2, 328.08) = 16.38$, $MSE = 9125.42$, *H-F* $p < .001$, *partial* $\eta^2 = .079$). Pairwise t-test comparisons with Bonferroni adjustment identified significant differences between combined ($\bar{\chi} = 70.06$) and pictorial ($\bar{\chi} = 57.55$) question types ($p < .001$), as well as between combined and symbolic ($\bar{\chi} = 61.97$) question types ($p < .001$), but not between pictorial and symbolic question types ($p > .05$). However, unlike our third-grade group, the difference in performance between question types persisted throughout the delayed post-test ($F(2, 352.154) = 62.522$, $MSE = 25313.102$, *H-F* $p < .001$, *partial* $\eta^2 = .246$). Follow-up pairwise comparisons with Bonferroni adjustment identified significant differences between pictorial ($\bar{\chi} = 34.52$) and combined ($\bar{\chi} = 54.40$) question types ($p < .001$), as well as between pictorial and symbolic ($\bar{\chi} = 52.38$) question types ($p < .001$), but not between combined and symbolic question types ($p > .05$). Thus, in fourth grade, the effect of question types began at post-test 1 and, unlike the third-grade sample this effect persisted into long-term retention on post-test 2.

Effects by Instructional Configuration: Group vs. Individual

The next sub-question was: Does percentage of class time spent in different *instructional configurations* (e.g., *groups* vs. *individually*) differ between VM and PM groups? We conducted a repeated measures t-test to compare time students spent engaged in whole group versus individual instruction for each representation (pictorial, symbolic, and physical/virtual manipulative). The third-grade repeated measures analyses found no significant difference for the PM group between percentage of time students used representations in whole group instruction compared to when they worked individually (Figure 9). However, a trending difference was found for the VM group [t(6) = 2.221, $p = .068$], with students spending

Figure 9. Comparing Time Spent Individually or in Group Instruction for Third-Grade PM (top) and VM (bottom) Groups



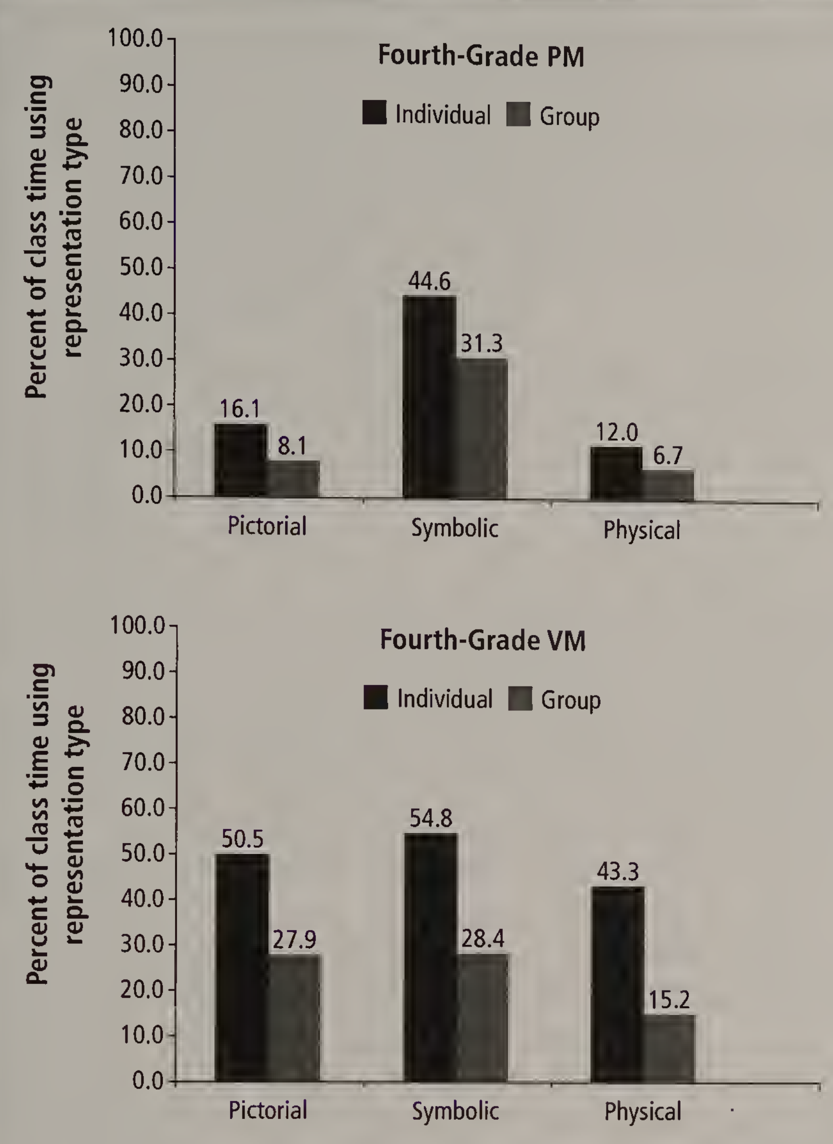
more class time working individually (M = 38.61%) compared to participating in whole group instruction (M = 18.14%). This trend is not surprising because the students using virtual manipulatives in the computer lab frequently worked individually on tasks at their own computers.

In fourth grade, the repeated-measures analyses found no significant difference for the PM group between percentage of time students used representations working in whole groups compared to percentage of time they worked individually (Figure 10). Conversely, a significant difference was found for the VM group [t(6) = 3.074, $p = .022$], which spent significantly more class time working individually (M = 38.9%) compared to working in a whole group (M = 16.99%). Again, this significant difference was expected due to the individual nature of using virtual manipulative tools in a computer lab classroom. No further statistical differences were found.

Effects by Fraction Representation Type: Pictorial, Symbolic, Manipulative

The next sub-question was: Does percentage of class time spent using each type of fraction *representation* (e.g., pictorial, symbolic, manipulative type) differ within and between VM and PM

Figure 10. Comparing Time Spent Individually or in Group Instruction for Fourth-Grade PM (top) and VM (bottom) Groups



classrooms? Repeated measures ANOVA were conducted on the observation data collected within each classroom, which indicates the amount of time each representation was used in both settings. For third-grade classrooms, a significant main effect of representation type was identified ($F(5, 38.98) = 3.11$, $MSE = 703.987$, $H\text{-}F\ p = .034$, *partial* $\eta^2 = .206$), which indicates that the amount of time spent using each representation differed significantly. No other comparisons were significant in third grade.

Identical comparisons were then conducted on the fourth-grade sample: Here, again, repeated measures ANOVA identified a significant main effect of representation type ($F(5, 48.302) = 15.08$, $MSE = 4368.976$, $H\text{-}F\ p < .001$, *partial* $\eta^2 = .519$). Also, a significant interaction between representation type and classroom type (VM or PM) was identified ($F(5, 48.302) = 3.426$, $MSE = 992.281$, $H\text{-}F\ p = .020$, *partial* $\eta^2 = .197$). Similarly, a significant main effect of classroom type (VM or PM) was identified ($F(1, 14) = 17.96$, $MSE = 6198.52$, $p = .001$, *partial* $\eta^2 = .562$), driven by greater overall use of each type of representation in VM compared to PM classrooms in fourth grade. These results indicate that the amount of time dedicated to each representation differed depending on PM or VM classroom representations.

Interaction Effects Between Instructional Configuration and Fraction Representation

The final sub-question asked: Are there interaction effects of class time spent in different instructional configurations by fraction representation? In other words, as these representations were often used both individually by each student as well as in a group setting, we were interested in whether or not the duration of use of each representation differed across individual and group settings. In our third-grade sample, follow-up pairwise comparisons to the repeated measures ANOVA described in the previous section, with Bonferroni adjustments, identified significant individual differences between time spent using pictorial representations individually ($\bar{x} = 35.45$) and VM-PM manipulative types in a group setting ($\bar{x} = 21.59$) ($p = .022$), as well as between VM-PM manipulative types and symbolic representations used in a group setting ($\bar{x} = 29.89$) ($p = .005$). No other comparisons were significant for third grade.

Similar analyses conducted in fourth grade identified multiple significant differences between representation usage. Symbolic representations used individually were far-and-away the most often used representation type ($\bar{x} = 50.91$) in fourth grade, therefore many of the significant pairwise comparisons emerged as a result of direct comparison with this representation type. For instance, time spent using VM-PM manipulative types individually ($\bar{x} = 28.4$), pictorial representations in a group setting ($\bar{x} = 18.52$), and VM-PM manipulative types in a group setting ($\bar{x} = 10.93$) all differed significantly from time spent using symbolic representations individually ($p < .01$). Similarly, as VM-PM manipulative types in a group setting were the least overall used representation ($\bar{x} = 10.93$) in fourth grade, every comparison other than pictorial representations used in a group setting differed significantly from it ($p < .05$). These results indicate that the amount of time dedicated to each representation often differs depending on instructional configuration (e.g., individual or group). In other words, not only does representation usage differ across the teaching method being used (e.g., VM or PM), but this pattern of usage also depends on the instructional configuration (e.g., individual or group).

LIMITATIONS

Even in studies in which students are randomly assigned and treatments are clearly described, we acknowledge that these are not laboratory settings. Students' responses and actions may unintentionally be influenced by a context in which they are not participating in mathematics learning with their regular teacher, their own beliefs about participating in research, and teacher and researcher expectations. "We have also long known, both from experiments and everyday experience, how subjects' behaviors are affected by expectation, context, and measurement procedures. The notion that there can be 'neutral' methods for gathering data has been refuted decisively" (Ericsson & Simon, 1981, p. 17).

Another limitation was the possibility of teacher effects which we attempted to reduce by ensuring that the instructors in the 17

VM groups and the 17 PM groups (a total of 34 instructional groups) had similar backgrounds and teaching experience, taught the same mathematics content daily, and adhered to a set of guidelines for the use of physical and virtual manipulatives. In this study with a large number of classrooms and different instructors, we attempted to address the potential impact of different teachers on student performance by ensuring that lesson content was the same on each day of the mathematics lessons and by observing over 70% of the classroom instruction. Furthermore, as using either physical or virtual manipulatives produced similar student learning of fraction concepts, results suggest that even when there could potentially be differences between a large number of instructors, student achievement remains equal across these different mathematics instructional modalities. Repeated measures ANOVA indicated that test scores (i.e., pre-test, post-test 1, post-test 2) did differ significantly across individual classrooms involved in the study ($F(13,54) = 7.79$, $MSE = 389.0$, p .001). However, despite this difference across classrooms, an insignificant classroom × instruction group PM vs. VM) interaction indicated that students' instructional group did not differentially mediate test score outcomes across classrooms that differed in test performance ($F(13,54) = 1.77$, $MSE = 88.7$, $p > .05$).

An additional analysis of the potential demographic predictors behind these achievement results was beyond the scope of this paper. A separate paper, using a variety of demographic variables (e.g., socio-economic status, English language learner status, and gender) in a linear regression analysis, examines these potential predictors (Moyer-Packenham, Jordan, et al., 2013). The results of the additional analysis revealed that fewer demographic predictors of student performance (e.g., socio-economic status, English language learner status, and gender) existed during fraction instruction using virtual manipulatives. When instructors used virtual manipulatives, there was an equalizing effect on achievement in third and fourth grade, in that fewer demographic factors were influential in the VM groups.

DISCUSSION

This study utilized the following design elements: 1) large numbers of student participants; 2) within-class random-assignment of students to treatment groups; 3) delayed post-tests to measure retention effects; 4) observations to document fidelity of instructional treatments, consistency of mathematical content, and representation use; and, 5) instrument development using IRT. The overarching finding was that, when uniquely combining multiple elements of a rigorous research design, no differences in overall achievement or fraction learning and retention emerge in third- and fourth-grade classrooms where virtual manipulatives are compared with classrooms using physical manipulatives and text-based materials. Essentially, when students were exposed to the same mathematics content and the same types of representations and spent about the same amount of time learning mathematics content in individual or group configurations, student performance on mathematics assessment measures of learning and retention were equal.

Within the context of this broad research finding, important results also emerged from our sub-questions. First, student objective ability, based on pre-test student score in relation to class pre-test average, predicted fraction achievement, learning, and retention in both VM and PM classrooms. Specifically, in both third and fourth grades, students with high objective ability showed a greater increase from pre-test to post-test 1 than did students with low and medium objective abilities. In addition, scores for students with high objective ability remained higher between post-test 1 and the delayed post-test than did scores for students with low and medium objective abilities. Therefore, student objective ability was a reliable predictor of fraction learning and performance in multiple classroom format modalities. Students' pretest scores, in relation to the class pretest average, are related to their learning and retention on the fraction tests administered in this study; this held for both VM and PM classroom modalities.

Secondly, we found that the impact of virtual manipulative use on students' fraction achievement was modulated by mathematics content test question type. The impact of question type on student achievement was of longer duration for fourth graders than for third graders. For fourth grade, as with third grade, students did better on combined question types, but this effect persisted longer for fourth graders. On post-test 2, fourth-grade students also performed better on symbolic than pictorial question types.

The current study shows that percentage of class time spent using fraction representations in groups vs. individually differed between VM and PM classrooms. Specifically, in third grade there was a trend to spend more class time using representations individually in VM but not in PM classrooms, and in fourth grade this difference reached significance. This was not surprising because individual students were at individual computers using virtual manipulatives in a computer classroom. Percentage of class time spent using each type of fraction representation was compared between VM and PM classrooms. In third grade there was no significant difference between percentage of class time spent using each type of representation in VM or PM classrooms. In fourth grade the VM classrooms spent significantly more time than PM classrooms using the manipulative representations. However, the results on time spent individually versus group work and the differences in the use of representations did not produce significant differences in students' learning or retention.

In our final interaction analysis, percentage of class time that students spent using each type of representation differed according to instructional configuration (individual vs. group). For example, in third grade, students spent more group time using symbolic representations than manipulatives. In fourth grade, the amount of time spent using symbolic representations individually was greater than any other representation type/instructional configuration, and time spent using manipulatives in a group was less than any other representation type/instructional configuration. Thus, amount of time using each representation differed significantly according to instructional configuration (e.g., individual or group).

IMPLICATIONS FOR PRACTICE

With very few significant differences between the VM and PM groups, what are the implications for classroom practice? First, we hope our results will help to put to rest the persistent question: Which is better—physical or virtual manipulatives? These results, based on a rigorous research design, demonstrate that using either physical or virtual manipulatives produce similar student achievement for third- and fourth-grade students learning fraction concepts. Overall, our results reveal that experienced instructors can use different instructional modalities for mathematics instruction and produce similar achievement results.

Another implication for practice is that classroom teachers can use pretests to identify students who may have particular difficulties during a mathematics unit of study, and provide specific RtI intervention during the unit to support those students identified as "Low."

The importance of students' facility with representations and tools was confirmed. For example, two mathematical practices in the *Common Core State Standards* (e.g., model with mathematics and use appropriate tools strategically) are integral to students' learning. A lack of familiarity with different representations can negatively influence students' understanding. In this study, students learned to use physical or virtual tools, and both instructional media supported their short-term learning from the pre- to the post-tests.

Finally, these results suggest that there are a variety of instructional configurations and representation that can produce learning gains. For example, students in a VM classroom have a greater opportunity to learn from representations individually (as opposed to sharing these representations in groups); similarly, students in VM classrooms may have greater exposure to pictorial representations of fractions, while students in PM classrooms have greater exposure to working with symbolic representations. However, all of the groups experienced quite a loss of learning based on the retention scores on the delayed post-test. With various instructional modalities, it was still difficult to retain knowledge and learning of fraction concepts for these third- and fourth-grade students. An important avenue for future research is to determine how to strengthen and solidify learning so that students not only learn the fraction concepts, but also retain the mathematics concepts.

CONCLUSION

This study addressed the need for large-scale, random-assignment, school-based, delayed effects research on virtual manipulatives compared with instruction using texts and physical manipulatives. Results revealed no significant overall differences in achievement between the VM and PM treatment groups when multiple elements of a quasi-experimental design were utilized. Additional results showed that student objective ability predicted fraction achievement in both VM and PM classrooms; the impact of virtual manipulative use on students' fraction achievement can be modulated by mathematics content test question type (e.g., symbolic vs. pictorial); percentage of class time spent using fraction representations in groups vs. individually can differ between VM and PM classrooms; and percentage of class time spent using each type of fraction representation (e.g., pictorial vs. symbolic) can differ between VM and PM classrooms, potentially providing differential opportunities to learn through each type of instructional modality.

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Cognitive Theory of Multimedia Learning, Instructional Design Principles, and Students with Learning Disabilities in Computer-based and Online Learning Environments

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ABSTRACT

Struggling learners and students with Learning Disabilities (LD) often exhibit unique cognitive processing and working memory characteristics that may not align with instructional design principles developed with typically developing learners. This paper begins with an explanation of the Cognitive Theory of Multimedia Learning and underlying Cognitive Load Theory and Baddeley's Theory of Working Memory. A review of five empirically supported design principles based on these theories (redundancy effect, modality effect, split attention principle, worked samples, and expert reversal effect) and of cognitive and memory characteristics of students with LD prompts questions for further research. Implications for computer-based and online learning environments are discussed.

Computer-based learning environments, including online learning, are becoming increasingly prevalent in K–12 public and private schools (Clark, Nguyen, & Sweller, 2005). Surveys conducted during 2007–08 indicated that over a million U.S. students were accessing online or blended (online with some face-to-face teacher contact) K–12 courses. This level of participation is a 47% increase over 2005–06, and accounts for 2% of all U.S. K–12 learners (Picciano, Seaman, Shea, & Swan, 2012). In light of these data, Picciano and colleagues estimated that by 2016, 5 million K–12 students would be accessing online and blended courses.

Potentially more important than these increases are the types of students who are accessing online and blended instruction. Seventy percent of all K–12 online and blended courses are accessed by high school students (Picciano et al., 2012). Although schools broadly indicated they offered online courses to meet diverse needs of learners, nearly 70% of surveyed schools specifically indicated they used online instruction for credit recovery purposes and 35% for remedial courses (Picciano et al., 2012). Although no federal definition of or reporting about credit recovery exists, in practice the many structured approaches for students to earn missed credits in order to graduate are funded by Title I and Individuals with Disabilities Education Act (IDEA) (McCabe & St. Andrie, 2012). From these data we infer that many students who access online learning are adolescents who have demonstrated limited academic success, perhaps in some cases related to LD.

Cortiella (2011) reports the following data on students with LD. Recent estimates place the number of U.S. school age students with LD at 2.5 million, which represents 5% of all K–12 students. More than 60% of students with LD receive a majority of their educational programming in a general education setting. They often demonstrate academic difficulties, with nearly half of all students with identified LD performing more than three grade levels below their peers. This achievement gap generally continues to expand as the students move from grade to grade. By the time they reach high school, the gap is as wide as it has ever been, leaving them at greater risk for behavioral outbursts, dropping out, and continued school failure. We suggest that online learning technologies and instructional design have the potential to exacerbate or ameliorate the risks to achieving academic success for these struggling students.

A current and continuing need for online and blended instructional technologies to adapt to and support the needs of students taking remedial and credit recovery courses, including those with LD, is readily apparent. However, the preponderance of research in computer-based and online instructional design is based on typically achieving students, and little is known about how current design principles and practices interact with the unique cognitive processes of students who struggle with learning. The purpose of this article, therefore, is to: a) describe the Cognitive Theory of Multimedia Learning and two important underlying cognitive theories; b) highlight some of the unique cognitive processing characteristics of many struggling learners and students with LD; c) highlight the need for research related to multimedia instructional design principles for students with LD; and d) conclude with implications for computer-based and online instructional design to support students with LD.

OVERVIEW OF COGNITIVE THEORIES THAT SUPPORT COMPUTER-BASED AND ONLINE INSTRUCTIONAL DESIGNS

"Good instructional design is driven by our knowledge of human cognitive structures and the manner in which those structures are organized . . ." (Sweller, 2005, p. 19). Based on this premise, Mayer and colleagues (Mayer, 2002, 2003, 2005; Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Mayer, Heiser, & Lonn, 2001; Mayer & Moreno, 1998, 2002, 2003; Moreno & Mayer, 2002; Moreno, Mayer, Spires, & Lester, 2001) developed an evidence base for the Cognitive Theory of Multimedia Learning (CTML). Multimedia learning has its roots in the cognitive architecture that allows human learning to take place and the technological features that best support cognition. CTML purports that construction of

new knowledge comes from receiving information via two channels, auditory and visual, which the human mind organizes and integrates with each other and with prior knowledge retrieved from long-term memory (Baddeley, 1986, 1999; Paivio, 1986; Sweller, 2005). This construction of knowledge is constrained by working memory (WM) capacity, and learning processes (e.g., attending to relevant incoming information) (Baddeley, 1986, 1999; Chandler & Sweller, 1991; Mayer, 2002; Sweller, 2005; Wittrock, 1989). CTML is particularly relevant to computer-based and online learning environments where auditory and numerous forms of visual stimuli (e.g., text, diagram, photo) are easily used and integrated into a curriculum.

Various instructional design principles from CTML were entailed and initially validated with typically developing students using paper-based texts and diagrams, and oral or recorded audio presentations (e.g., Bobis, Sweller, & Cooper, 1993; Conati & VanLehn, 2000; Mayer et al., 1996; Mousavi, Low, & Sweller, 1995; Reder & Anderson, 1982; Renkl, Stark, Gruber, & Mandl, 1998; Schworm & Renkl, 2002; Solman, Singh, & Kehoe, 1992). Subsequently the theory and principles were extended to and validated in computer-based or online environments, particularly with typically achieving college students (e.g., Antonenko & Niederhauser, 2010; Atkinson 2002; Atkinson, Renkl, & Merrill, 2003; Berthold, Eysink & Renkl, 2009; Cerpa, Chandler, & Sweller, 1996; Craig, Gholson, & Driscoll, 2002; Fiorella, Vogel-Walcutt, & Schatz, 2012; Huff, Bauhoff, & Schwan, 2012; Kalyuga, Chandler, & Sweller, 1999; Mayer et al., 2001; Mayer & Moreno 1998; Moreno & Mayer, 2002; Moreno et al., 2001; Renkl, 1997, 2002; Schnotz & Bannert, 2003; Sweller & Chandler, 1994; Wecker, 2012). Despite the robust body of literature supporting CTML among typically achieving college students, little is known about whether and how the theory and related instructional design principles fit with the unique cognitive characteristics of K–12 students with LD.

Baddeley's Theory of Working Memory and Cognitive Load Theory

As background for exploring how CTML relates to the cognitive characteristics of students with LD, we briefly review Baddeley's Theory of Working Memory and the Cognitive Load Theory, which were foundational to the origin of CTML. Although other competing WM theories exist, Mayer relied on Baddeley's (1992) WM theory—the most widely accepted and researched WM model (Berg, 2008)—and the Cognitive Load Theory (Sweller, 2005) to formulate the CTML.

Early cognitive research established that WM has limitations. Miller (1956, 1994) found that a typical WM holds about seven elements of information for about 20 seconds. Further, typical WM can process (i.e., combine, contrast, or manipulate) about 2 to 4 elements of information (Sweller, 2005). Baddeley described three mechanisms within the WM framework that relate to these WM limitations: a central executive (CE) that coordinates the WM processes and two subsystems, a visual/spatial processor, and a phonological loop or auditory processor (Sweller, 2005). The CE has four main tasks: a) focus attention; b) divide attention between more than one task as necessary, c) switch attention back and forth, and d) communicate with long term memory (Baddeley, 2012). The visual/spatial sketchpad stores visual and spatial information and is also responsible for creating and interpreting mental images (Swanson & Saez, 2005). The phonological loop acts as a temporary storage facility for verbal information, including subvocal speech and sounds. These three WM mechanisms interact with incoming information.

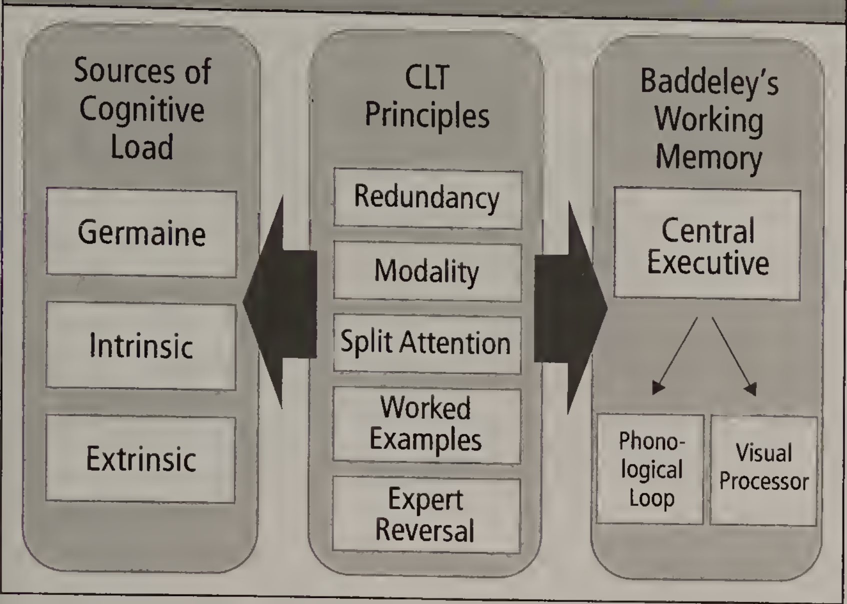
Cognitive Load Theory (CLT) further develops the ideas of WM limitations in relation to learning. This theory, originated in the 1980's by Sweller and developed by others in the 1990s, continues to influence research into cognitive processes and instructional design (Clark & Mayer, 2011; Paas, Renkl, & Sweller, 2003). CTL asserts that learning novel information is more difficult when limited WM capacity is overloaded with information and processing demands, otherwise referred to as cognitive load. Sweller (2005) outlined three types of cognitive load: extraneous, intrinsic, and germane. Germane cognitive load is referred to as good cognitive load placed on the WM during schema construction and knowledge building. Intrinsic cognitive load is the inherent level of difficulty associated with instructional materials, directly tied to information or content. Generally, content that is simple with few interacting elements has a lower intrinsic cognitive load. Content that is high in interactivity requires more cognitive resources to process, and therefore has higher intrinsic cognitive load. Extraneous cognitive load is created by unnecessary information that usurps cognitive capacity that could otherwise be used for handling germane and intrinsic cognitive load; extraneous load is often a result of poor instructional design (de Jong, 2010). Therefore, CTL suggests that instruction should be designed in a way that recognizes WM channels and load limitations so that learners can thoroughly process novel information (Kirschner, 2002; Paas et al., 2003; Paas & Van Merrienboer, 1994).

Thus, the CTML holds that multimedia instruction must take into consideration the channels and forms of cognitive load in relation to a learner's WM limitations. Generally instruction that reduces the extraneous cognitive load placed on WM during knowledge construction can benefit the learning process. Further, computer-based and online learning environments are particularly viable means for engaging learners' visual and auditory channels. Thus CTML, which applies CLT to multimedia formats, suggests that instructional design principles can mediate between the sources of cognitive load and the elements of WM in ways that either help or hinder learning (see Figure 1).

OVERVIEW OF UNIQUE COGNITIVE PROCESSES OF STUDENTS WITH LD

Collectively, these three theories of cognition and learning have been heavily researched with students who have typical memory and other cognitive capacities. Likewise, the current state of the

Figure 1. Cognitive Learning Theory Design Principles That Mediate the Relationship Between Sources of Cognitive Load and Elements of Working Memory.



research on multimedia design features and their use in computer-based learning environments is based on typically achieving students. However, a significant body of literature outside of multimedia and online learning reports that many students with LD have limitations in WM processes in general and, more specifically, deficits in CE functioning. Therefore, we briefly summarize research on these unique cognitive processes among students with LD as a basis for discussing their relation to CTML-based design principles.

Swanson and Saez (2005) contended that, "Limitations in WM have a neurological/biological base. These limitations are multifaceted as to the psychological operations they influence. Limitations in WM cause LD." (Swanson & Saez, 2005, p. 183). They specifically cited studies indicating deficits in the CE for students with LD. The CE has several components: controlled attention, recall capacity, updating, planning, and mapping. A key factor affecting CE of students with LD is the controlled attention component. They define controlled attention as "the capacity to hold and maintain relevant information in the face of interference or distraction" (Swanson & Saez, 2005, p. 184).

Students with LD seem to have a limited recall capacity when compared to same age peers. Recall deficits have been demonstrated across verbal and non-verbal tasks indicating more than just language-based processing deficits (e.g., Geary, 2004; Geary, Hamson, & Hoard, 2000; Jordan & Hanich, 2000; Swanson & Saez, 2005). Importantly, students with LD demonstrated recall rates that were at the same level as same age peers when the task demands of the activity were low (three component strings), however as the cognitive load on WM increased (six component strings) the differences between the two groups became apparent (Swanson & Saez, 2005).

Another aspect of CE deficit that some students with LD demonstrate compared to same age peers is in the area of updating (e.g., Swanson, Howard, & Saez, 2006; Swanson & Saez, 2005). Updating refers to the ongoing process during knowledge construction of coding and monitoring incoming information and then accurately adjusting information already held in WM accordingly. These deficits in CE have been demonstrated at a variety of ages (children and adults) indicating that students with LD do not have a developmental delay in WM, but a sustained deficit in WM compared to their same age peers (e.g., McLean & Hitch, 1999). Updating deficits were present even when other factors were statistically controlled (i.e., IQ, academic achievement, and domain specific knowledge). Further, the deficit was unrelated to the types of deficits found in students with other WM limitations such as Attention Deficit Hyperactivity Disorder (ADHD) (Swanson & Saez, 2005).

Students with LD also may demonstrate difficulties in the phonological loop processor. Deficits in this subsystem relate to the retrieval of verbal information. Some individuals with LD have demonstrated an inability to accurately retrieve language-based information (e.g., deHirsch, 1974; Goodglass & Kaplan, 1993; Johnson, 1995; Mattis, 1978; Rosenbek, LaPointe, & Wertz, 1989). Students with LD do not necessarily have deficits in all areas of CE, but generally in at least one of these areas.

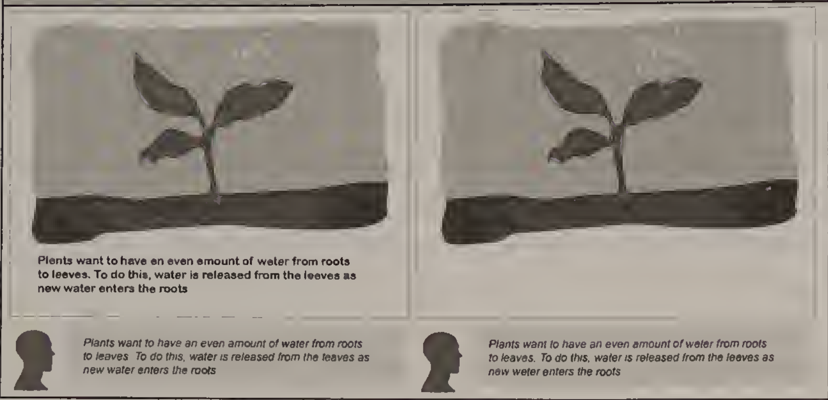
CTML INSTRUCTIONAL DESIGN PRINCIPLES AND STUDENTS WITH LD

Instructional design refers to "the entire process of analysis of learning needs and goals and the development of a delivery system to meet those needs" and includes "development of instructional materials and activities; and tryout and evaluation of all instruction and learner activities" (The University of Michigan, 1996, p. 1). From CTML come five empirically supported instructional design principles that may be relevant to any part of the design process: a) redundancy effect, b) modality effect, c) split attention principle, d) worked samples, and e) expert reversal effects. The principles apply to any format of multimedia instruction, but are especially important in the context of computer-based and online learning because in order to construct knowledge and develop understanding, "learners are exposed to material in verbal (such as on-screen text or narration) as well as pictorial form (including static materials such as photos or illustrations, and dynamic materials such as video or animation)" (Mayer & Moreno, 2002, pp. 87–88). Therefore, we next describe each of these principles, summarize the state of research, and consider unanswered questions in relation to students with LD in online learning environments.

Redundancy Effect

The redundancy effect refers to the negative effect of repeated material that hinders rather than supports learning outcomes (Sweller, 2005). Redundancy occurs when information is presented in two or more ways, but only one is needed for full understanding. Redundancy can also occur when a single form of delivery presents information that contains unnecessary explanatory information. Both practices increase the cognitive load of a

Figure 2. Redundancy Effect. The redundancy of audio and text (left panel) increases the amount of information being monitored and processed by the learner and, thus, negatively impacts cognitive load. Presentation of an image and audio (right panel) produces less strain on the learner's working memory.



task, and therefore may reduce learning outcomes. In computer-based learning environments, the redundancy effect is most often encountered when identical information is presented to learners by two or more forms of media (e.g., graphic, text, audio) (see Figure 2). This design feature increases the extraneous cognitive load, and can decrease learning outcomes for typical students (Sweller, 2005).

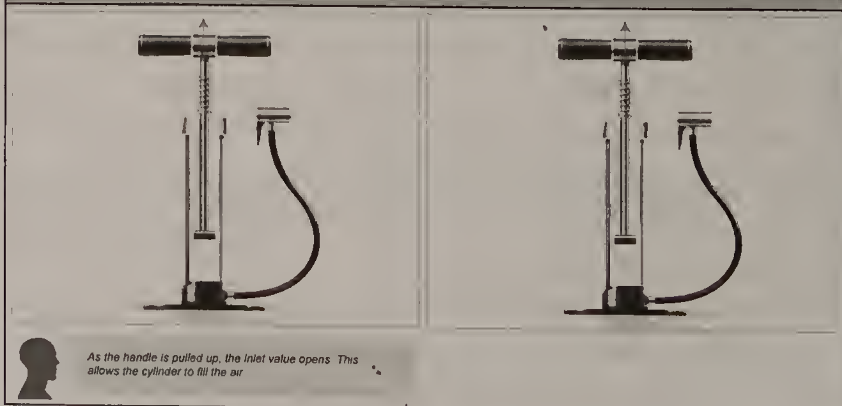
Only a few studies of the redundancy effect have been conducted with samples from the K–12 population, and these were with typically achieving learners. The studies demonstrated the redundancy effect in the context of instruction in sight word development, (Solman et al.,1992), reading comprehension (Reder & Anderson, 1982), basic geometry (Bobis et al., 1993), and biology (Liu, Lin, Tsai, & Pass, 2012). For example, Liu and colleagues (2012) identified a redundancy effect in their study of 81 typically achieving middle school students and mobile computer learning (tablets). The learning outcomes were examined by student inclusion in one of three groups: text and pictures; text and real objects; and text, pictures, and real objects. Students in the text/picture and text/object group significantly outperformed students in text/pictures/objects condition in comprehension (d = .56 and .57, respectively) and learning efficiency (d = .71 and .72, respectively). The addition of pictures when objects were already present (or vice versa) increased cognitive load for the task and reduced learning outcomes. Therefore, in a computer-based learning environment, information presented in text, if already presented in another way, may not be helpful and may possibly be deleterious to performance for typically achieving students. The research on redundancy does not, however, indicate which modality is better, only that redundant information via multiple modalities can decrease knowledge construction (Sweller, 2005).

Redundancy is a relatively settled construct for typically achieving students, but the literature includes little information about whether the effects of redundant information are the same for students with LD. Although in past studies researchers have found improved reading outcomes from the use of text-to-speech software (Dimmitt, Hodapp, Judas, Munn, & Rachow, 2006; Izzo, Yurick, & McArrell, 2009), these studies do not specify whether the subjects were reading the text at the same time as listening or only listening. As a result, they do not address whether the simultaneous transmission of information through two media (i.e., redundancy) adversely affects outcomes as a result of creating cognitive load. One might argue that providing multiple means of representation of the same information helps ensure all students have access to the curriculum. Alternatively, the argument could be made that multiple representation could be distractions that interfere with the controlled attention component within the CE of students with LD. Because students with LD often have difficulty adjusting to changes in content, format, and mode of response (Myers & Hammill, 1990; Swanson, 1996), research is needed to determine if online systems that provide multiple means of representation enhance or distract from learning for students with LD.

Modality Effect

The modality effect refers to the positive impact of mixed presentation of information in visual and auditory modes, which reduces the cognitive load of knowledge construction and results in an expansion of WM available capacity (Low & Sweller, 2005). These representations are not redundant information, rather, they are complementary, and each mode is essential to a complete understanding (see Figure 3). The information presented visually would be unintelligible without the auditory information and vice versa (Low & Sweller, 2005). The modality principle focuses on the WM's dual channels (visual and auditory) for processing new information (Clark & Mayer, 2011). Each of these channels has a limited capacity to process new information, and should one of these channels become overloaded, a barrier to knowledge construction would likely be created (Crooks, Cheon, Inan, Ari, & Flores, 2012). The suggestion is that online environments and curriculum may be enhanced if their designs take into account the modality effect and divide the load between channels. However, Tabbers, Martens, and van Merrienboer (2004) demonstrated a

Figure 3. Modality Effect. The air pump depicted with complementary spoken text along with the graphical explanation (left panel) allows learners to integrate information using two different types of processing. The air pump without spoken text (right panel) does not. The mixed presentation of information (left panel) demonstrates an integration of the modality effect.



reverse modality effect (i.e., college students in the text group outperformed students in the audio group, ($n = 111$, $d = -0.46$); they attributed this finding to the fact that the lesson was learner paced instead of system paced.

Little, if any research demonstrating the modality effect among the K–12 population, with or without LD is reported in the literature. However, from the several studies of the modality effect among college students in computer-based learning environments, the weight of evidence shows that under certain circumstances, typically achieving *novice* learners benefit greatly from dual modality access to new information. Research indicates that being able to share the cognitive load of the task with two processors (visual and auditory) leads to greater knowledge construction for typically developing students. Specifically, students are likely to benefit from auditory narration rather than reading words when they are also required to process other visual information (Low & Sweller, 2005).

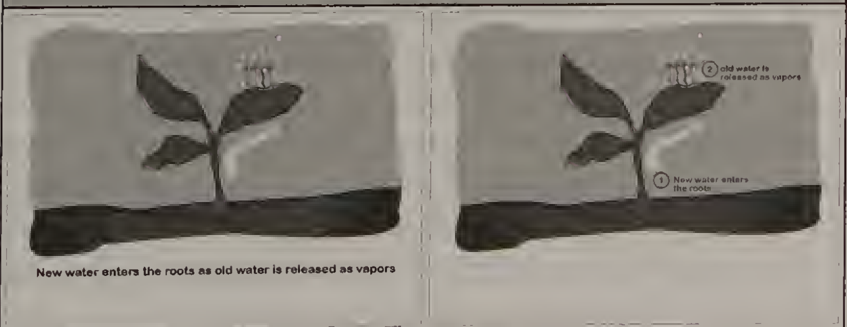
Based on Baddeley's theory of WM (1992), the argument could be made that among students with LD, who often display CE process deficits, dual modalities may decrease learning rather than better utilize WM capacity to increase learning. Such students often have limited ability to coordinate the visual/spatial processor and the phonological loop/auditory processor, and therefore may not make the necessary connections among vital information presented in dual modalities. Thus, research is needed to determine if the modality effect holds true for K–12 students with LD. In addition research is needed to ascertain whether and what type of support is needed to help students with LD effectively coordinate information from a visual source with information from an audio source to ensure incoming information does not stand alone and unintelligible in their minds.

Split Attention

The split attention principle refers to the negative effect on knowledge construction that is a result of dividing attention between two relevant forms of information (e.g., diagrams and text, or animation and text). Splitting a learner's attention will increase extraneous cognitive load and reduce knowledge construction (Ayres & Sweller, 2005). Not integrating necessary information is one common way that split attention is created. For example, a diagram may be presented to students depicting a concept while written text identifying key information about the diagram is presented underneath or next to the diagram (see Figure 4). This presentation requires students to split the attention of their visual processing and waste cognitive energy mentally integrating the diagram and the text. Split attention is closely connected to the modality effect in that the modality effect is an instructional design feature that seeks to mitigate effects of the split attention principle.

The split attention principle has been observed in studies of typically achieving middle and high school students using a computerized manual with integrated text and diagrams (Cerpa et al., 1996), and using worked samples (Mousavi et al., 1995). The negative effects of spit attention may be exacerbated for students with LD. Visual perception difficulties are often co-morbid with or causal factors of LD (e.g., Eden, Stein, Wood, & Wood, 1995; Espinda, 1973; Silver, 1989). Further, research cites controlled attention as a key factor affecting CE of students with LD (Swanson & Saez, 2005). Thus, questions exist about online design features that split attention between audio and visual inputs or multiple visual inputs. For example, To what existent does spatially contiguous information detract or enhance learning for students with LD? Research is still needed to understand the impact of non-optimal visual images on the achievement of students with LD, and whether and how subtext from images should be incorporated into images to enhance learning for students with LD.

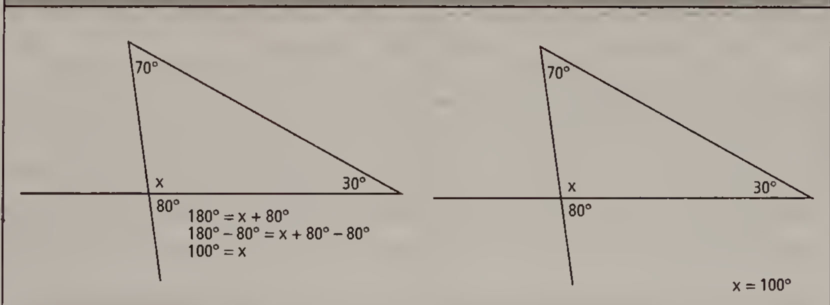
Figure 4. Split Attention Principle. Instead of requiring learners to split their attention between the image and the text at the bottom of the screen (left panel), the split-attention principle states that the same information should be blended in so that learners are not required to split their attention between the two different locations (right panel).



Worked Samples

Worked samples have been shown to have a positive effect on learning. Worked samples refer to examples of correct solutions presented to students as a part of the knowledge construction process. They generally exist in math and science or other problem-solving processes that require multiple steps (see Figure 5). They consist of a) a rule or principle, b) an accurately completed problem with all necessary steps, and c) additional "to be solved" problems for independent practice (Renkl, 2005). When novice learners begin work on a problem with multiple steps, they focus on the solution to the problem at hand, which often has a very high intrinsic cognitive load and leaves little processing capacity to

Figure 5. Worked Samples. A worked sample (left panel) includes a step-by-step process to solve the problem instead of simply providing the solution (right panel). The inclusion of the step-by-step explanation of how to solve the problem is an example of a worked sample.



tackle the underlying rule or principle. Focusing on the solution to a problem does not lead to deeper understanding or knowledge construction. However, worked samples allow students to utilize more processing capacity on the overarching rule or principle and less on solving the problem. When cognitive resources are allocated in this way, students may achieve a deeper understanding of the principle.

Best practice is to have a specific plan for removing the worked sample supports as students begin to make their own connections to the rules and principles demonstrated in the worked samples, a process called self-explanation. During this cognitive process students fill in information for themselves and make connections between the worked samples and similar unsolved problems, thereby becoming more proficient in finding solutions and explaining concepts. Salden, Aleven, Schwonke, and Renkl's (2010) study of typically achieving high school students, some of whom were in vocational education, addressed the balance between providing sufficient instructional assistance on the one hand and self-regulated generative learning on the other hand in the case of worked samples. They showed that adaptive fading of instructional assistance was crucial for effective learning as the method outperformed a fixed fading method on immediate post-testing ($d = 0.48$) and delayed post-testing ($d = 0.58$).

Such findings with typically achieving students are consistent with decades of findings in special education research that support the use of explicit instruction with students with LD (e.g., Chung & Tam, 2005; Fuchs, Fuchs, Hamlett, & Appleton, 2002; Graner & Deshler, 2012; Owen & Fuchs, 2002; Palinscar & Brown, 1987; Sawyer, Graham, & Harris, 1992). Although explicit instruction includes more than simply worked samples with adaptive fading, the implication is that intelligently design worked samples in computer-based environments may be appropriate for students with or without disabilities. However, research questions remain such as: What are the best ways to promote self-explanations? What data elements and computerized algorithms should lead to added or removed prompts or connection to worked samples? Do students with LD need additional instructional assistance with worked samples, and if so what types of assistance?

Expert Reversal Effect

The expert reversal effect refers to the unintended reduction in the effectiveness of instructional tools as a learner increases in domain specific knowledge. Kalyuga (2005) explained the foundations of this effect "as levels of learner knowledge in a domain changed, relative effectiveness of instructional formats reversed, design principles that helped low-knowledge learners did not help, but hindered, high-knowledge learners" (p. 327). He suggested that as students develop more knowledge in domain areas, the instructional procedures should move along the continuum from high to low structure. By advancing procedures along this continuum, students will be encouraged to continue developing their knowledge constructions while keeping cognitive load at a manageable level. To expert learners, a multimedia approach can often be redundant, and the instructional designs that had previously been effective (e.g., dual-modality, worked samples) may instead increase the extraneous cognitive load.

Oksa, Kalyuga, and Chandler (2010) demonstrated that the expertise reversal effect was observed in both well-structured and ill-structured domains, where high school age novice learners performed better, and expert learners performed worse in the presence of guided instruction and explanatory notes. Homer and Plass (2010) indicated that among typically achieving middle and high school students the effect was related to both domain-specific prior knowledge and the general developmental level of learners. Thus, computer-based instructional components may need a reverse scaffolding of multimedia supports as typical learners demonstrate expert levels of content knowledge (Kalyuga, 2005). However, as with the other design principles, questions remain for students with LD. For example, Do students with LD experience an expert reversal effect? If so, does the reversal occur in the same way or at the same stage of learning as among typical students? Which of a learner's deficits are permanent and need sustained instructional support throughout learning (i.e., do not demonstrate expert reversal effects)? What, if any, developmental shift across age ranges occur in instructional support needs (i.e., how does age relate to expert reversal)?

IMPLICATIONS FOR PRACTICE IN COMPUTER-BASED AND ONLINE LEARNING

Although more research is needed to determine the implications of CTML instructional design principles for students with LD, instructional designers and practitioners can consider what has been learned to date that suggests implications for computer-based and online learning environments.

First, when developing instruction for typical students, CTML suggests that we enhance germane cognitive load to support schema construction (Mayer, 2005). In general, good designs do this through well-organized instruction that identifies the course/lesson objectives, builds on the student's background knowledge, and provides necessary scaffolding (e.g., worked samples) to support knowledge building, the latter especially important in online learning as there may not be a teacher or peer nearby to help. However, research is clear that many students with LD have WM limitations that go beyond the limitations experienced by most other students (McLean & Hitch, 1999; Swanson & Saez, 2005). LD research indicates that these students have problem with recall, retrieval of verbal information, and updating—signaling an even greater need for attention to instructional designs that enhance germane cognitive loads. Therefore, as teachers currently support students with LD, they should select online learning environments and curriculum that are well structured, provide overviews, outline making connections between concepts-ideas, and provide or prime background knowledge.

Appropriate instructional designs also take into account intrinsic load, that is, the load placed on WM as a result of the complexity of

the content (Sweller, 2005). LD research indicates that, if task demands are limited, students with LD learn as well as their non-disabled peers. We also know from research that students with LD benefit when content is divided into small instructional chunks (e.g., Gobet, et al., 2001). By doing so, some of the effects of WM limitations may be circumvented. Thus, a second possible way to support students with LD is to select online learning environments and curriculum that present content in small, simple formats that have limited interacting elements.

With regard to extraneous cognitive load resulting from poor instructional design, ideally online designs will reduce this negative load by applying the principles associated with redundancy, modality, split attention, worked samples, and expert reversal effects (Crooks et al., 2012; Kalyuga, 2005; Liu et al., 2012; Mousavi et al., 1995; Salden et al., 2010). To reduce the extraneous load created by simultaneously presenting the same information through multiple channels (i.e., redundancy), it is suggested that teachers choose a curriculum that does not contain substantial simultaneous presentation of information. On the other hand, by capitalizing on the modality effect, online environment designs can spread the cognitive load between dual processing channels by presenting necessary content using two modes (e.g., presenting different content via audio and visual media) (Clark, & Mayer, 2011; Crooks et al., 2012). However, caution is advised for students with LD whose CE functioning may not allow them to coordinate information from multiple modes. Indeed, some research has suggested a reverse effect when the students were allowed to use self pacing in their interaction with the curriculum (Tabbers et al., 2004).

Students with LD are known to be challenged by controlled attention and integration and, therefore, may have difficulty with splitting attention when viewing related images and texts in online environments (Swanson & Saez, 2005). Research has shown that two focal points can hamper learning in typically developing students as well (Ayers, & Sweller, 2005). For these reasons, we infer that good designs for any student will use images with important information incorporated into them rather than in subtitles below the images, which results in two focal points. Unnecessary images have the potential to create redundancy and split attention effects. Images presented only to improve the appearance of a web page or online program can negatively affect learning for all students, perhaps more so for students with LD. Thus, good online learning environments judiciously use images that are relevant to the learning content.

Lastly, curriculum and online learning environments that use worked samples can benefit all students. However, worked samples have the potential to create an expert reversal effect for students with greater understanding of the concept being taught. As a practical matter, well-designed online learning environments allow teachers or systems to manage cognitive load by switching on and off worked samples and other forms of instructional support based on individual student need.

CONCLUSION

Computer-based education and online learning environments designed from the Cognitive Theory of Multimedia Learning and associated empirically derived principles are likely to be appropriate for typically achieving students. However, such technology-based instruction may not take into account the working memory limitations and central executive functioning deficits that are common among students with LD or those who struggle with learning. Therefore, as online learning technologies and practices continue to mature and advance for typically achieving students, educational research must begin to make progress in understanding the relationships among the cognitive processes of students with LD and multimedia instructional designs. Research initiatives are currently underway to understand the redundancy and the split attention effects among students with disabilities engaged in online learning (e.g., Greer, Ingram, & Mayer, 2013). Until this research and other efforts increase our understanding of these relationships, and the findings are reflected in online instructional designs and teacher practices, students with LD or those who struggle with learning are not likely to experience maximum benefits in online and blended learning environments. Meanwhile, as a practical matter, educators who utilize computer-based or online learning environments can begin to evaluate their current systems, asking whether the cognitive load and instructional design features hinder or enhance learning for their struggling students.

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The Scaled Arrival of K–12 Online Education: Emerging Realities and Implications for the Future of Education

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ABSTRACT

Dramatic increases in K–12 online education for all students, including those in traditionally underserved populations, necessitate a reconceptualization in the way educators plan and implement instruction. In this article the authors examine the complex array of variables and implementation models that must be accounted for during the pivot from a purely brick-and-mortar educational system to one that makes use of both virtual and blended environments. The authors call for enhanced emphasis on instructional goals and design principles, rather than the capabilities of available technology. They conclude that educational leaders and researchers must play a role in three key areas: using technology to enhance the accessibility and usability of curricular materials to meet the needs of different types of learners, advancing the understanding and practices of in-service and pre-service teachers through preparation that focuses on online learning, and fostering collaboration between educational researchers and technology innovators and developers to build a research base that will inform K–12 online education.

INTRODUCTION

In a frequently cited book based on his noted study of two Silicon Valley high schools, Cuban (2001) documented how computers were generally underutilized or misused in support of traditional forms of instruction. At that time, Cuban argued that use of technology in education was like forcing a square peg in a round hole and predicted that this condition would continue until schools adopted new practices, or technology was designed to better support education.

At the same time as educators began their struggle to use technology effectively, other fields had already begun to meaningfully integrate technology in ways that drastically enhanced, profoundly changed, or significantly reduced the cost of practice. For instance, medicine's integration of technology brought about such innovations as Magnetic Resonance Imaging (MRI), greatly changing medical practices by allowing physicians to look inside a body without performing invasive exploratory surgery. In manufacturing, output in the United States grew substantially as technology was deployed, but costs (by way of jobs) were drastically reduced (de Rugy, 2011).

Fast-forward 12 years since the publication of Cuban's book (2001); the power of technology is beginning to drastically shape the practice of education. The building insurgence of Kindergarten through 12th grade (K–12) online education has the potential to alter the landscape of the educational system in ways that are similar to the effects of technological innovations on other fields. Currently 40 states have state-level virtual schools or state-led online initiatives (iNACOL, 2012), 31 states have fulltime virtual or online schools (Watson, Murin, Vashaw, Gemin, & Rapp, 2012), and several states have reported a continual year-to-year growth rate of over 100% in the number of students participating in online education (Watson et al., 2012).

This growth pattern is not a simple matter (Kim, Kim, & Karimi, 2012). It comes at a time of upheaval as efforts to appropriately provide all students with an education that will address the larger needs of a modern society and economy are joined with efforts to meet the criteria of success on traditional assessments of student growth (Basham, Israel, & Maynard, 2010). For instance, No Child Left Behind (NCLB) (2001) paved the way for school districts to measure student success primarily by paper-based assessments and demanded that schools find ways for nearly all students to demonstrate continual annual progress on these assessments (Ravitch, 2010). This mandate emerged at a time when the evolution of new technology began to drastically alter our cultural practices, and the educational system was looking for new ways to educate students, identified as digital natives, who were learning more from modern technology than ever before (Prensky, 2001). To answer the needs of education (as well as grow new markets), the technology industry has begun to develop and deploy systems for preparing students for higher test-based performance (e.g., Study Island, http://www.studyisland.com/).

Concurrent with educational mandates and new technology, some educational leaders have begun to understand that the world's economy is shifting from regionalized markets to more global, interconnected markets (Darling-Hammond, 2010). The transformation of the workplace requires students to conclude their K–12 school experience with vastly different knowledge and skills in order to be successful (Darling-Hammond, 2010; Zhao, 2012). To support the wider needs of students, programs such as New Tech Schools (http://www.newtechnetwork.org/) use online technology interwoven with a brick-and-mortar school curriculum to support a problem-based learning environment that encourages students to use more college and career ready skills (New Tech Network, 2013). Viewed holistically, K–12 online education is meeting a variety of needs within the educational system, yet for many, the idea of K–12 students receiving some or all of their education through an online system is foreign and new.

The notion of K–12 online education may come as a surprise to some, but in reality, distance and even online education has been in practice for decades (Cavanaugh Gillan, Kromrey, Hess, & Blomeyer, 2004). That said, a search of peer-reviewed literature, especially empirical research, provides little descriptive understanding, explanation, or evidence supporting online education (Rice, 2006). In fact, a large majority of the information resides in government and industry driven reports (e.g., Means, Yukie, Murphy, Bakia, & Jones, 2010) and white papers (e.g., Rhim & Kowal, 2008). The research literature in peer-reviewed journals is largely limited to studies of K–12 students that were conducted by pioneering researchers such as Cavanaugh (2001), Collins (2001), Frid (2001), and Rice (2006).

The term, K–12 online education, as used in this article, is defined as an educational program where the student learns at least partially through online delivery of content and instruction with some element of student control over time, place, path, and/or pace. Importantly, some of the program may also be supervised in a brick-and-mortar location. As will be discussed later, online education can be divided into two distinct types: completely online (usually called virtual) and blended instruction. In virtual learning environments, students are completely immersed in learning in an online setting. In blended instruction, students are taught through a combination of online instructional delivery and face-to-face experiences.

In this article we review the current conditions and theoretical models associated with K–12 online education and discuss implications of online instruction for educational leaders and practitioners. The discussion is intended to help shape educators' understanding of K–12 online learning as well as create momentum for future research, including more refereed empirical studies. Ultimately, our purpose is to make a contribution to improving online education for all students, including underserved populations.

Much of our understanding is built on the work conducted at the national Center of Online Learning and Students with Disabilities (COLSD). Opened in 2012, the primary mission of COLSD is to conduct research on various dimensions of online learning with respect to accessibility and effectiveness for K–12 learners with disabilities. Although the authors of this article are associated with the COLSD, the principal work is that of the authors only.

CURRENT CONDITIONS IN K–12 ONLINE EDUCATION

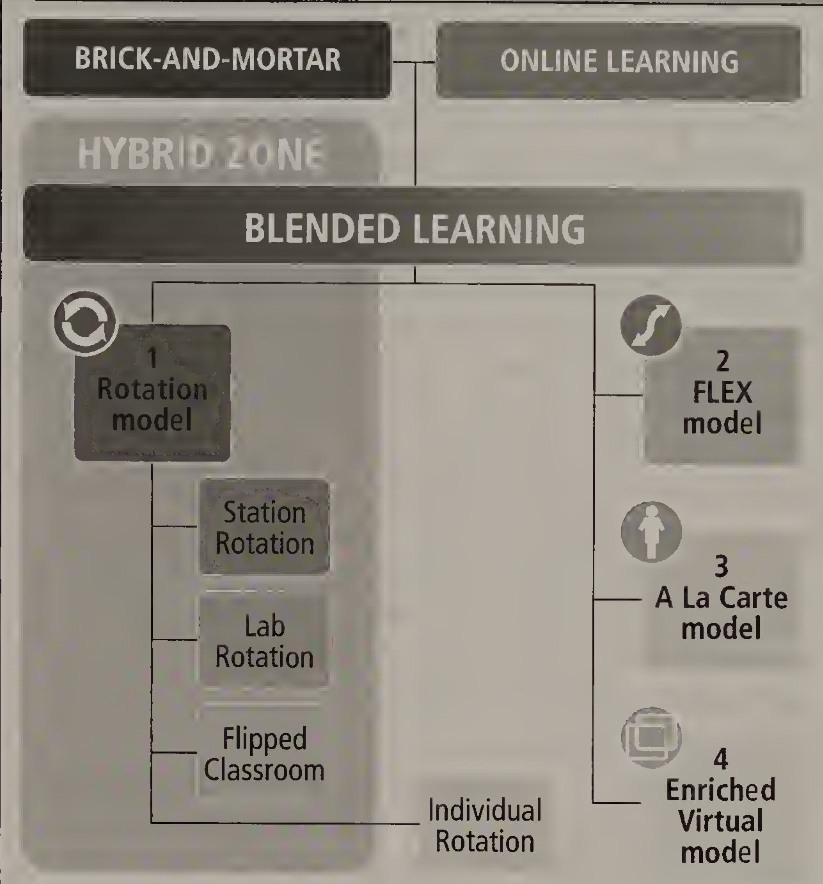
The focus on investing in and developing new technology for the education sector has never been greater (Shah, 2012). In addition, new technology has allowed the world to become more connected and engaged (Shirky, 2011). As a result, information has become decentralized, and school attendance or participation in formal learning activities is no longer required to gain knowledge. For instance, a person with an interest in or a need for help in math can access Khan Academy (http://www.khanacademy.org/) without cost, or use a tool such as Wolfram Alpha (http://www.wolframalpha.com/). The same person, regardless of place, time, or age can also view or even participate in solving complex mathematical problems on math community blogs with renowned mathematicians, such as Fields Medal recipient Timothy Gowers (e.g., http://gowers.wordpress.com/). Likewise, video-conferencing technology (e.g., Skype, Adobe Connect) can bring the teacher to the student's kitchen table offering just-in-time instruction without the student or teacher leaving the confines of their respective homes. All signals agree with Christensen, Horn, and Johnson's (2008) predictions of an emerging disruption of the traditional education sector with online education as a driving force. Specifically, they predict that, by 2019, 50% of all courses in grades 9–12 will be delivered in online learning environments.

Field-based and government indicators provide a clear picture of online education beginning to take shape within the K–12 educational system. For instance, nearly every state has some form of state-led initiatives in online education, and 31 of these states have statewide full-time online schools (Watson et al., 2012). Together, state online schools have seen an ongoing substantial increase from more than 320,000 online K–12 course enrollments during the 2008–09 school year (Wicks, 2010) to 620,000 full-time course enrollments in the most recent school year (Watson et al., 2012). Although virtual schools and online courses in K–12 education are not required, and many do not report the number of students they serve, one source estimates that over 1.8 million students were served during the 2010–11 school year (iNACOL, 2012). Likewise, Watson and colleagues (2012), using a variety of data sources, suggest that the total number of students currently participating in online education is likely closer to several million, or around 5% of the total school population.

Although 5% of the student population may not seem large, the reality becomes clearer when the growth rate is further investigated. Measuring online course growth in traditional school districts, EdNet (2011) found that in 2010 only 34% reported having online courses, yet a year later, 75% of the districts reported having fully online classes. Moreover, Queen and Lewis (2011) found that 74% of the districts reported they wanted to significantly increase their online programs in the next one to three years. The planned expansion is not surprising given the high level of interest many students have in taking online courses. According to Watson and colleagues (2012) various states have seen huge growth rates with online student enrollments over the last four years. In fact no state, except Kansas (-5%), has reported a decrease in online enrollment during the same period. Even in the state of Kansas the number of districts offering completely online programs has tripled in the past two academic years (J. Noble, personal communication, November 30, 2012). Many states, including Wyoming (+1,038%), Florida (+796%), Utah (+515%), Oklahoma (+337%), South Carolina (+303%), Texas (+211%), Hawaii (+200%), Georgia (+146%), and California (+121%), have reported over 100% growth in K–12 online enrollments over the same period (Watson et al., 2012). Moreover, some states, such as Arizona and Ohio, are already serving well over 35,000 students in full-time online schools (Watson et al., 2012).

As could be predicted through the concept of disruptive innovation, the largest populations of students enrolled in online settings are traditionally identified as underserved. For instance, a survey of 2,310 public school districts across all 50 states and the District of Columbia reported that 62% of online education courses were identified as credit recovery, 47% as dual enrollment, 29% as advanced placement, 27% as technical education, and 65% were categorized as other academic (Queen & Lewis, 2011). Not surprisingly, these districts reported the significant majority of online course offerings resided at the high school level. Moreover, the survey found that these public school districts considered the following variables as important or very important when deciding to offer online education: offering courses for credit recovery (72%), providing courses not available (71%), reducing scheduling conflicts (68%), offering AP or college courses (61%), meeting the needs of students with disabilities or who are homebound (55%), providing accelerated credit accumulation for early graduation (42%), resolving space limitations (16%), and generating new revenue (13%). Finally, as various underserved populations experienced notable increases in online education, the largest year-to-year growth was noted for students with disabilities. This growth was so surprising that Glick (2011) identified it as an area of needed concentration and critical concern for further investigation.

Figure 1. Blended Learning in Relation to Current and Fully Online Educational Practices (Christensen, Horn, & Staker, 2013)



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MODELS OF K–12 ONLINE EDUCATION

As may be expected in a relatively new and fast growing field, various forms or models of practice have emerged. As a whole, online learning can be divided into two primary categories. The first category can generally be defined as fully online, and the second as a blend of online and face-to-face instruction.

Fully online schools and classes are sometimes referred to as *virtual*. Even though the school may be housed in a brick-and-mortar building, the students never attend this facility. Across the online sector, students enrolled in completely online or virtual schools make up the smallest but growing population. For instance, during the 2011–12 school year, at least 275,000 students attended fully online schools. Reporting the number of students is not required, and therefore, the true student population is likely higher. Over the past few years, virtual schools have averaged an annual growth rate of 15% (Watson et al., 2012).

By far the largest impact online education has made across the educational system is in the second category, that is, blended learning. According to Christensen, Horn, and Staker (2013) blended learning is distributed among four primary models (see Figure 1). The first of these, the Rotation Model, is described below.

The Rotation Model

The *Rotation Model* holds that students move in and out of online instruction based on schedules or teachers' decisions. Christensen et al., (2013) have identified four current approaches to blended instruction within the Rotation Model: *station rotation, lab rotation, flipped classroom*, and *individual rotation*.

In the *station rotation* model, students rotate through in-classroom stations (or centers), where at least one of the stations provides for online learning (Christensen et al., 2013). Students can work individually, in small groups, or in large groups to accomplish the tasks established for each station. These tasks can include any number of activities (e.g., read, listen to, watch, write, build, draw) with the intended outcome contributing to student learning goals. An example of this approach is a classroom with multiple stations (or centers) with one of the stations focused on a computer-based, personalized, independent reading program designed to increase achievement among struggling readers. The program allows for students to move at their pace and is specific to their goals, as directed by the intervention and the teacher.

According to Christensen and colleagues (2013) in the *lab rotation* model, students rotate across multiple locations on a brick-and-mortar campus where at least one activity is lab-based and one involves online learning. Within the broader Rotation Model, the lab may be the online component of the rotation, and students rotate across multiple locations within the same campus. In an expansion of the model, these locations may be centrally located on a single brick-and-mortar campus, or they may be beyond the walls of the campus in the physical, rather than the virtual world. For instance, this approach could include a means to support off-campus internships or work experiences. Christensen et al., (2013) noted that the lab rotation model is different from the station rotation model because it takes place in multiple locations, rather than a single room. To clarify, we believe the more important characteristic of

this approach is that it involves some form of learning lab work. The location of these activities makes no meaningful impact on design of learning; rather, activities are divided between online learning labs and the traditional classroom.

The *flipped classroom* is a Rotation Model in which the students rotate on a fixed schedule between online delivery of content and instruction, generally outside of the classroom, and face-to-face teacher-guided practice (or projects), generally in a classroom setting (Christensen et al., 2013). This approach flips the way students use homework and class time, wherein homework time (after traditional school time) is spent receiving content information online at the students' own pace, and class time supports practice and problem-solving.

The *individual rotation* model is like other Rotation Models because it involves students moving between online and teacher-facilitated learning. The difference between this approach and other Rotation Models is that it is personalized around the students' needs (Christensen et al., 2013). These needs may relate to variables such as primary language differences, the pace of instruction, and how the student engages in associated work products (e.g., interdisciplinary projects, traditional papers). In this model, students generally receive instructional delivery through an online system that has some personalization features, supplemented by activities such as seminars and group projects/collaboration in a brick-and-mortar setting.

The Flex Model

Christensen and colleagues' (2013) second major blended learning model is the *Flex Model*. Within this model, there are no pre-scheduled instructional times; instead students move through the online content based on their own schedule within a brick-and-mortar location, which is staffed by teachers-of-record and other adults who provide students with needed support in a variety of ways. These include one-on-one or small group instruction in breakout rooms and curriculum-based projects, which could be a small group activity. The main difference between the individual rotation and the Flex Model is that students determine their own instructional schedule in the Flex Model. Primary to this model is that students receive flexible support on an as needed basis. This model relies on personalized online systems, teachers-of-record, and other adults to continuously use data, such as student performance analytics from the online system, to know how to best support each student in accomplishing predetermined goals.

The *A la Carte* Model

The *A la Carte Model,* the third major model presented by Christensen et al. (2013), involves students who choose to supplement their traditional coursework with an online course. Significantly, the actual online learning can be distributed to any location such as a traditional brick-and-mortar school or an off-site location. As we interpret this model, the school may or may not be supporting or even have knowledge of the student taking the supplemental coursework. For instance, a student may be taking a generic programming course at the local high school and then go home and take the free iOS (Apple's mobile operating system) programming course offered by Stanford University in iTunes U.

The Enriched Virtual Model

Finally, Christensen and colleagues (2013) described the *Enriched Virtual Model*, a blended education model, which is generally designed to support a completely virtual experience. This approach is designed as a whole-school model in which students spend most of their time online and only periodically come to a brick-and-mortar location for support or enrichment associated with the online education. For instance, a virtual school may offer a brick-and-mortar location where students can physically gather to work on group projects, receive supplemental one-on-one support in an academic area, or attend special workshops on such specific skill areas as interviewing.

These forms of blended instruction demonstrate the breadth of options that schools have for using online instructional technology. However, each of these models treats online technology as only a part of a broader set of instructional choices designed to accomplish learning goals. For instance, in a chemistry course, online instruction may work well for building declarative knowledge about the periodic table of elements, but an in-person lab experience is better suited for discovering the physical properties of chemical interactions, in which such properties as odor and texture are important. Key here is that instructional goals and design, rather than the capabilities and availability of technology, define the relationship of a student to online instruction. To support this concept, Repetto, Cavanaugh, Wayer, and Liu (2010) highlighted the need for online education systems to support the 5Cs of education (connect, climate, control, curriculum and caring community). In addition, an online learning environment should connect the students with meaningful experiences, provide the appropriate climate for growth and understanding, give the students the ability to control their own learning, offer an engaging curriculum that uses evidence-based teaching practices, and ensure a learning community that is caring. Simply thinking of online education as being driven by technology, rather than instructional design, limits the ability to accomplish the desired outcomes.

THE IMPLICATIONS OF ONLINE LEARNING FOR K–12 EDUCATION

Transformative policy and practice initiatives have occurred since Cuban (2001) called for schools to adopt new practices for using technology and/or for the technology industry to align the design of innovations with the needs of education. Schools and districts across the nation have adopted online learning practices as a means of serving previously underserved students (e.g., credit recovery and advance placement courses). Further, many schools have integrated online technology with face-to-face instructional activities for better learning outcomes among all students. Likewise, the technology industry has responded to Cuban's call by

incorporating pedagogically appropriate features (e.g., integration of learning supports in video games, text readers, and other tools integrated in web systems) to better support education.

Online education has become an impetus for major transformation in K–12 education. However, before a complete disruption occurs, we believe district/building leadership, teachers, teacher educators, educational leaders, and researchers should move quickly to purposefully shape a modern learning environment that makes use of online and blended practices. Therefore, we believe three specific efforts require the attention of education leaders and researchers:

1. Move schools toward a more purposeful understanding that technology use is only one part of sound instructional design.
2. Develop in-service and pre-service teachers' skills for designing and applying purposeful instructional design that makes use of technology as well as pedagogical strategies to achieve desired learning objectives.
3. Work with technology innovators and developers to build a research base of online tools as well as instructional methods for supporting the needs of all learners, including those with disabilities and those in other underserved populations.

A More Purposeful Understanding of Technology in Instructional Design

Consistent with Cuban's earlier findings, a recent study found that 97% of teachers reported having one or more computers in their classroom, yet, only 29% reported technology use during instruction on a regular basis (Gray, Thomas, Lewis, & Tice, 2010). Educational leaders must help schools move beyond the acquisition of technology for technology's sake and toward more purposeful use of the available technology. Decades of research support the idea that technology must be integrated with effective instructional design that includes purposeful strategies in order to produce student learning (e.g., Papert, 1980; 1994; Papert & Harel, 1991; Sandholtz, Ringstaff, & Dwyer, 1994).

In the context of the rapid infiltration of online technology delivery systems, the same risk of underutilization or misuse of technology exists. Unless online learning systems are placed in classrooms for pedagogically appropriate purposes, and rely on research-based principles of instructional design, teachers and students are less likely to benefit from them. Too often educators think the technology will provide the needed engagement and instruction without much consideration of a host of other instructional variables (Carnahan, Basham, & Musti-Rao, 2009). When educators rely solely on technology to provide for student learning, and the desired outcomes are not realized, the technology, rather than the instructional design, is viewed as the cause of the failure. Appropriate technology use requires a purposeful design that accounts for such environmental factors as existing learner variability, desired instructional goals, outcome measures, and the use of both instructional strategies and technology/tools to accomplish the desired outcomes (Basham, Meyer, & Perry, 2010).

The evidence-based instructional design framework Universal Design for Learning (UDL) (CAST, 2011), for example, proactively addresses learner variability within the educational environment. Barriers (e.g., cultural, physical, social, cognitive) that limit the accessibility of the curricular materials are identified and circumvented at the outset of the design process using multiple means of representation, action, expression, and engagement. Further, UDL supports the notion that student variability is not limited to disability. This is different from many design frameworks that force students to conform to the system, rather than providing for the system to adapt to the student. Within UDL students are provided with multiple ways to engage, access content/information, and demonstrate understanding (CAST, 2011).

In practice, UDL uses both technological tools and instructional strategies in a "backwards design" process to support desired outcomes (UDL-IRN, 2011). Within this framework, educators identify the instructional goals and design the measures of success and the instructional experience that consider learner variability as well as the potential barriers within the content and the environment. To provide for variability and to overcome barriers, the learning experience contains multiple means for students to engage, multiple means in the way content is represented to the student, and multiple ways by which the student can demonstrate understanding of the content. Upon delivering the instruction, formative assessment data are continually gathered and used to inform the educators on the success of the design. An iterative process of design is used to achieve the desired learning outcomes and allow for incremental changes to be made in the instruction and/or the environment to maximize outcomes.

Unfortunately, Stahl, Smith, and Basham (2012) found that K–12 online learning providers are lacking key accessibility and usability features that support the implementation of UDL (CAST, 2011). Moreover, without providing students and teachers with key strategies for how to use the online curriculum (e.g., predict, rewind, pause, use in conjunction with this concept map), lessons that integrate online tools can actually cause more harm than good. We suggest that educational leaders place more emphasis on acquiring and using online learning technology that operationalizes personalized environments and embrace the concept of learner variability regardless of student abilities, disabilities, language, or learning preferences. As a starting point, leaders should consider how both tools and strategies are purposefully used to achieve desired outcomes. As a framework, UDL provides a research-based foundation for thinking about, applying, and building personalized learning environments.

In-service and Pre-service Teacher Education

As previously indicated, schools risk underutilization or misuse of technology if the systems are not integrated with sound instructional design. Even so, the risk is not fully mitigated nor opportunities fully realized unless teachers are prepared to use the technology, including online and blended learning, as well as instructional strategies to yield the desired outcomes. Too many

teacher educators and professional development providers have been slow or lacking in integrating technology into the curriculum and the instruction that serve as models. Over a decade ago, the well-documented seminal research of Moursund and Bielefeldt (1999) found that one of the largest contributing factors to a teacher's lack of technology use during instruction was lack of understanding of how to appropriately use technology in instructional practice. More recently, a survey conducted by Gray and colleagues (2010) reported that very few teachers learned how to use computing technology in undergraduate and graduate education classes. So we are not surprised that 78% of the teachers reported that they still needed to learn how to independently use technology in their classrooms. Overall, we should be disappointed by the small progress that has been made in teacher preparation and staff development for using technology in instruction.

To address these deficiencies, a number of initiatives seek to require teacher education students and current educators to reflect comprehensively on how technology applications will interface with pedagogical principles, the structure of the content, and the students' individual learning needs (Smith & Okolo, 2010). Koehler and Mishra (2005) have developed an instructional design framework known as technological pedagogical content knowledge (TPACK) that seamlessly integrates technology, content, and pedagogy for design and delivery of various types of content. For the past seven years, TPACK has expanded from a conceptual framework to an integrated instructional approach that includes ways to measure teacher technology competency (Archambault & Crippen 2009; Schmidt et al., 2009). Educators who benefit from the TPACK framework recognize that technology is not a tool that can or should be thoughtlessly added to existing instruction. Instead, educators should select pedagogies that are a logical match for enhancing and enriching the content (e.g., Koehler & Mishra, 2005; Shulman, 1987). Technology should be considered only if this tool will interface with the selected pedagogy to help shape and deliver content in a way that would not possible without the use of technology.

While TPACK (Koehler & Mishra, 2005) is an excellent framework to offer teacher educators and school-based professionals an approach to expanding teacher technology competency, it is limited in the virtual learning paradigm. TPACK seeks to further technology application tied to effective instruction (e.g., pedagogy and content) in order to expand technology integration for the teacher and students. In blended and virtual models, learning is embedded in a system that requires a shift in how one teaches within this new learning structure. Thus, while Koehler and Misha's (2005) TPACK provides a stable foundation for understanding technology integration, especially in supporting teacher education and professional development, a more complete solution is needed for advancing teacher skill development required for current blended and virtual classrooms.

Instead, as current standards indicate (e.g., iNACOL, 2011), teachers need the skills to plan, design, and incorporate strategies that encourage active learning, interaction, participation, and collaboration in the online environment. They also need to develop skills that promote and offer regular, prompt, and ongoing feedback as well as the ability to construct and provide clear expectations to the learner and the adult (e.g., parent) who is supporting the child at home. In the virtual online environment particularly, teachers are increasingly required to develop collaborative as well as consultation skills to further engage, support, and empower the parent or adult in the home who is supporting, motivating, and reinforcing the student on a daily basis. Unlike brick-and-mortar settings, our initial findings indicate that virtual learning is engaging the parent or the adult as a co-teacher or at the very least, a paraeducator, and depending on the parent to implement instructional activities.

With respect to online learning, both practice and industry have surpassed the mindset, ability, and standards within the field of teacher education to understand the dynamics of the modern classroom in general, and online and blended learning in particular. At least two reasons for this lag come to mind. First, higher education may not have the resources to develop or attract and retain leaders who can provide the vision upon which to act. Second, higher education is often tied to slower moving entities such as state legislatures and accrediting boards, and may be moving toward the vision at a slower pace than industry and practice. It is critical that teacher education catch-up and even surpass the current practices of the field. A primary role of teacher education should be to provide leadership for practice as well as supporting the necessary open mindset for adopting new pioneering models. Without this leadership both future and current educators have limited models upon which to base their practice.

A Research Base of Online Tools and Instructional Methods for Supporting All Types of Learners

The empirical evidence to inform applications of technology in teacher preparation is either absent or in short supply (Lawless & Pellegrino, 2007). Frequently, the evidence presented to support the use of technology in teacher preparation takes the form of satisfaction reports from users (Clark, 2009). Many technology-based teaching methods do not specify a theoretical framework that provides the basis for, and justification of, the specific design features of the recommended interventions, surely a missed opportunity when considering the design and instructional implications of blended/online learning (Clark, 2009). In addition, while the majority of studies of technology in teacher education focus on user perceptions (Heilson, 2010), of those that do report student learning, the great majority report outcomes with technology in comparison to learning without technology (Schmidt et al., 2009).

In K–12 education, currently 75% of the districts offering online learning are associated with or even managed and staffed by for-profit companies rather than public education entities (iNACOL, 2012). That is, when districts begin offering online services they often contract with a company to provide the primary content, the instruction, and sometimes the instructional personnel

(iNACOL, 2012). From a student perspective, nearly all systems follow the same routine in which the student login and are directed through a series of instructional modules. Interestingly, these prepackaged modules are similar to those advocated by Skinner (1986) over 25 years ago. As Skinner demonstrated, machine-driven modules have the potential to rapidly yield powerful learning outcomes, especially with superficial learning (Eysink & de Jong, 2011). However, this type of technology also has the potential to drastically shape the workforce within education.

Unfortunately, prepackaged materials are often deployed in K–12 online education with little attention to empirical research-based design principles, instructional strategy integration, or teacher understanding. This dynamic has never been seen before in education. Our intent is not to say that online education companies are harmful to the system, but that as online education moves forward, educational leaders and researchers need to begin partnering with developers to support the design of better systems. The developers would benefit from reaching out to researchers and innovators in the field to better support the development of more evidence-based, personalized systems that meet complex student needs.

Perhaps one of the reasons industry leaders have moved ahead without partnerships with educational researchers is that foundational arguments regarding the approach to technology use in education have not been resolved. An example is the difference between a constructivist approach advocated by Papert and colleagues (Papert, 1980; 1994; Papert & Harel, 1991) and the behaviorist approach advanced by Skinner (1986). The inability to offer a common sense and real-world balance between dichotomous positions limits our own capacity to move forward as a field. This position also renders the field nearly powerless to cooperate, question, or purposefully respond to a company that wants to place the next "shiny widget" in schools. Rather than jumping into technology systems that recognize only one approach, educational researchers must investigate ways to provide for the development of different types of learners. At this point in time, we believe that blended environments provide a more balanced approach to online learning, and research initiatives to investigate and validate such approaches are vital next steps.

Another possible obstacle to industry-research partnerships is the inability to adopt more nimble and pragmatic research designs. To develop fruitful relationships, educational researchers must find ways to move at a more rapid pace to identify and implement purposeful research designs. Research that investigates both evidence-based practices as well as solutions for real-world learning environments is needed. For instance, research such as A/B testing provides a means to rapidly study design attributes of systems and system features for effects variables including student engagement and/or knowledge attainment (U.S. Department of Education, Office of Educational Technology, 2012). Moreover, methodologies such as Design-Based Research (DBR) or Design-Based Implementation Research (DBIR) provide means to investigate how technology and strategy are purposefully integrated and used in real-world environments to produce desired outcomes (Basham, Meyer, et al., 2010). Together A/B testing and DBR support a research structure to rapidly investigate meaningful instructional designs solutions for meeting the needs of many types of students.

Collaborative partnerships among developers, researchers, and schools are required to support the needed technology innovations and practical real-world pedagogical solutions to harness the power of online instruction. If the field desires better systems, we cannot sit idly by waiting for someone to develop them. Rather, we must become more involved in demanding as well as working with developers to design systems that are framed around validated instructional design frameworks, such as UDL (CAST, 2011). For instance, over the last few years, university researchers have been working with Filament Games (http://www.filamentgames.com/) to design UDL-based video games (see Marino, et al., 2012). Within this collaboration academic researchers work alongside Filament video game developers to critique and offer suggestions for the embedded features needed to support UDL-aligned video games. The researchers then study the video games to validate their design and efficacy to meet learner variability within classroom settings. This collaboration has produced award-winning video games that are effective for meeting educational needs across a variety of learners.

CONCLUSION

More than a decade ago, Cuban (2001) challenged the field of education to adopt new practices, and the technology industry to better support education for the benefit of students across the nation. Since that time, online and blended learning have virtually exploded onto the K–12 education scene and continue to grow rapidly. We believe that leadership is required if online and blended learning is to meaningfully impact education. A further need exists for a broader understanding of student variability and instructional design, and the development of teachers who are competent in the modern learning environment. Critical to all these outcomes is collaboration across the technology and educational research sectors. Our hope is that this discussion will help to shape our understanding as well as provide momentum for further investigation that leads to changes for the benefit of teachers and students, including underserved populations.

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Authors' Note

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Essay Book Reviews

ACADEMIC/PROFESSIONAL TEXT

BERNARD LUGER III, *Journal of Education*

Assessing the Educational Data Movement

BY PHILIP J. PIETY, 2013

New York, NY: Teachers College Press, 224 pages
ISBN: 978-0-8077-5426-9

In his new book, *Assessing the Educational Data Movement*, Phillip J. Piety addresses the modern debate over the use of educational data to make decisions for districts, schools, teachers, and individual students. Piety's uses the term *educational data movement* to refer to the development of technology that makes it possible for educational data to be integrated into the work of schools (p. xiii). He considers this trend to be inevitable and irreversible, and thus, focuses on the strengths and challenges that lie ahead for the educational data movement, rather than on the arguments that can be made against using data-driven processes. However, Piety also recognizes the uniqueness of the educational field and the potential problems that can be caused by a data driven movement. He acknowledges that while accountability policies that require data collection may be considered necessary, they are not neutral and often have negative side effects.

The book has four parts: Framing the Contemporary Sociotechnical Shift, Peripheral Educational Systems and Administrations, The Technical Instructional Core, and Enduring Challenges and Future Directions.

The first chapter, "The Educational Data Movement Begins," provides an explanation of the origins of the modern educational data movement. As recently as 2000, the use of data was rare in schools. Since then, there has been an increase in the collection and use of student and teacher data. While expenditures for other personnel including library and media specialists have been reduced, districts have added data analysts. Much of this expansion has been driven by federal mandates, in particular the No Child Left Behind Act. The rapid increase in data use, coupled with a perception that the educational enterprise needs to improve, has led to a *sociotechnical revolution* (p. 4). Piety offers four main observations:

1. The educational data movement is irreversible and cumulative.
2. Information tools are operating in education at both individual and organizational levels.
3. Educational data present unique challenges.
4. The educational data movement is still young.

It is common for educational theorists and researchers to criticize the new role that business management has assumed in school reform efforts (e.g., Hargreaves & Fullan, 2012). While acknowledging the complex relationship between for-profit businesses and the educational complex, Piety also asserts that there is much to be gained by using business models. He points to the long history that education shares with American business, going back to the early twentieth century. Piety also acknowledges that the industrial era model of assembly line production that was adopted by schools has been criticized by both civil rights leaders and educational researchers as both inequitable and ineffective.

To attempt to correct the inequities of the industrial era model, the standards-based model of education was developed in the 1980s, and while it was less prominent for several decades, with the adoption of the *Common Core State Standards* (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) by the vast majority of states, the reviewer suggests that the standards-based model now has a preeminent place in education in the United States. The deregulation of the educational enterprise that allowed for vouchers, charter schools, distance-learning, and for-profit universities attracted the involvement of philanthropic foundations. The interest in data that was common to these foundations, led to its external use for accountability and incentives, and internal use for providing teachers more information for better decision-making.

For readers who are unfamiliar with business technology and its uses, and the perspectives of business leaders regarding success, achievement, and education, Chapter 2 may be the most important chapter in the book. In order to show the commonalities between businesses and the educational enterprise, Piety uses Scott's 1987 model of a technical core with peripheral components and extends the model by adding executive management. An explanation of this model and the role of technology in transferring data between the elements is the focus of the chapter.

Beginning with the assertion that the main differences between businesses and schools are in the technical core, Piety defines this core as the work that the business or school is designed to perform. For a school the technical core is teaching students. The peripheral components are those functions and processes that are needed to operate the business or school but are not central to its mission, for example, payroll, purchasing, and accounting. Finally, the executive management is described as the governing structure that sets priorities for both the technical core and the peripheral components. Piety suggests that while the technical core in business and education differs, sometimes dramatically, the peripheral components and the executive management functions are remarkably similar.

Piety places technology in a special place in the technical core model. In many cases, technology resides within the technical core itself; in business, a robot might perform manufacturing functions, while in a school, a laptop might be used in instruction. However,

technology also acts as a *connector* and allows data transfer from the technical core to the peripheral components and the executive management functions. Thus, technology fills the role of *organizational integrator*. When the technology is successful in integrating the organization's functions, it becomes a *change agent*. Organizations that succeed are those that are most successful in using technology to adapt to change. Piety explains many of these technologies, describes how they are used in the business world, and notes that, in most cases, education has yet to adopt them.

The first two major technologies are *enterprise resource planning* (ERP) and *customer relationship management* (CRM). In the world of business, ERP integrates peripheral functions such as human resources and financial accounting with technical core functions, such as manufacturing and project management. CRM allows sales and marketing to interface with customer support and self-service functions. Together, ERP and CRM, when interfaced, provide a wealth of data to all levels of the business enterprise, becoming a change agent. Piety argues that education currently does not have effective ERP and CRM systems, and gathering data is both difficult and costly. Additionally, because most executive managers in education were themselves educators rather than business leaders, outside perspectives are needed to help refine the business-like functions of schools.

Piety also addresses the ways businesses have been successful with knowledge management (KM), and many would agree that collaboration among educators is vital to improved educational outcomes. Many of the technologies used in business could assist schools to increase the acquisition and sharing of knowledge; however, KM is in its infancy in schools—for example, the development of knowledge bases and wikis are common in business, but not in education.

Part II is centered on the history of technological advancements and implementation by states and school districts. Chapter 3 focuses on the large data collection projects initiated by the federal government and others. The Race to the Top program included among its goals, to develop data systems that show growth and can lead to instructional improvement. The Education Sciences Reform Act of 2002 required states to participate in the development of State Longitudinal Data Systems (SLDS) to allow data sharing across states and also, the development of *value-added models* (or VAM) based upon statistically linked test data. These systems allow for tracking students individually over time, which can provide real-time information to educators when decisions are made. Using the data in the SLDS, the Center for Analysis of Longitudinal Data in Education Research (CALDER) has been able to study many factors, including principals, licensure exams, and resource allocation. However, lack of quality data remained a pervasive problem until the Gates and Dell Foundations funded the Data Quality Campaign (DQC) in 2005, which is still in progress despite a goal to have all states up and running by 2010.

Chapter 4, Districts: Data Warehouses and Teacher Evaluation Systems, provides a history of the development of data warehouses and describes how people from the business sector have been integrated into school management. Without exception, these networked projects are financed by private foundations including: Broad Academy and Broad Residency, Educational Pioneers, and the Strategic Data Project. The major focus of their work is using data to enhance school performance. Graduates of these programs now hold positions in the federal Department of Education or as superintendents in major school districts in the United States. The public and policy makers should be aware that a relatively small number of foundations and individuals have been responsible for the development of a large segment of the professional educational staff in large school districts.

Part III focuses on the technical core, and how the use of data actually impacts student learning. Although school buildings look much the same as they did 20 (or even 50) years ago, one change that is visible in many schools is the "data wall," a public place where school performance data are posted for all students, families, and visitors to see and evaluate. In addition, teachers now tend to be more collaborative, and principals appear to be more engaged in daily instruction. What has been difficult to evaluate is whether or not these changes have been effective in increasing student learning.

Some studies have shown that increased testing has had negative unintended consequences for student learning. Research shows that some schools have focused resources on "bubble kids"—students whose test scores are close to the cut-off for the next highest score category—to the exclusion of teaching students who are further behind. Often, test data used to evaluate student performance were over a year old. Moreover, teaching practices adopted to improve student scores often failed to improve instruction or actively worked against effective instruction.

Many schools and districts, however, have successfully used data to improve instruction. Citing data from the 2009 Department of Education's Study *of Education Data Systems and Decision Making*, Piety offers the following insights regarding successful use of student data in schools:

1. Schools are dependent on the type of data available from their districts, and many districts lack fully integrated data systems and assessments for schools to use.
2. Schools progress through stages of data use, initially using data for accountability and improvement planning, later for more direct student-related purposes, and still later for instructional purposes.
3. Teachers use data more when led by their principals, and there is variation in the way different principals approach data in their schools.
4. Training and support are important for helping practitioners both to use the technology they have and to understand the meaning of the data they have.

According to Piety's analysis, the availability of good data is paramount. In some cases, teachers generate data by using formative assessments that yield up-to-the minute information on student

performance, but evidence of its use and outcomes is sparse. However, there is evidence to suggest that often the data are not collected in a systematic way—teachers may give a quiz, but the data are not recorded in the data warehouse, nor is the content recorded for later analysis. Some publishers have begun to include formative assessments with their textbooks, and the outcomes of these assessments are more easily integrated into student data streams.

Piety cites both the alternative teaching program Teach for America (TFA) and the charter school Knowledge Is Power Program (KIPP) for being innovators in the use of student data. TFA has been collecting student and teacher data from across the nation and using the data to predict the success of future teachers. KIPP, on the other hand, has realized that increase in test scores does not always predict college success, and they have collected and analyzed student data to determine the other factors that indicate success. The result of their inquiry is the student character report card that focuses on eleven categories that impact personal development and ultimately, success in college.

While some success has been realized by using data to analyze student performance, there has been less success in analyzing effective teaching. The landmark Measures of Effective Teaching study, funded by the Gates Foundation and led by Harvard professor Tim Kane, showed that the relationship between observation scores and student test scores was positive, although weak. While the value-added models did help predict student achievement, there was substantial unexplained variance. This has led to a reduction in reliance on value-added models in several government programs, including Race to the Top that has moved from 50% reliance of value-added measures in teacher evaluation to 35% reliance on the value-added models.

In Chapter 6, Piety considers how school culture affects teaching and learning. He endorses the findings of Edmonds and others that suggest that successful schools have principals who are *instructional leaders* and are school-based *professional learning communities* (PLC). Given the number of teachers in a large school, both instructional leadership and PLC's can benefit from the availability of reliable classroom data. However, Piety also asserts that school leaders need to be *professional managers* and cites the 2012 Wallace Foundation's five core areas that must be the focus of school leaders:

1. Shaping a vision of academic success for all students,
2. Creating a climate hospitable to education,
3. Cultivating leadership in others (which could include PLCs),
4. Improving instruction, and
5. Managing people, data, and processes to foster school improvement.

Piety describes programs that have developed to teach principals to be better professional managers by using data. These programs, which include New Leaders for New Schools, the National Center for Education and the Economy, and Rice University, have all developed programs to educate principals to become better professional managers, and the Rice University program offers an MBA degree program specifically for school leaders.

In Chapter 7, Piety considers how the Technical Core of schools and schooling could be changed by the use of data. Instead of the classical model, where teachers work alone within a single classroom and are responsible for all that happens there, Piety suggests that *personalized learning* can be accomplished with the use of data. Instead of presenting all students with the same lesson and then trying to help those students who have difficulty, it can become possible to present content to groups of students with similar levels of understanding. While acknowledging that large-scale personalization is only a conceptual dream at this point, the continued development of value-added models and individualized formative assessment can make greater personalization a reality.

Piety also describes technologies that could be used in the future to change schooling: the use of *activity traces* that follow students as they move through the material, *metadata* that record information about the characteristics of the materials used, and *paradata* that show the circumstances under which material is used. Collectively, all this information is *big data* and can be analyzed by big computers to find compelling patterns across large groups of students. Much of the data could be collected as students participate in *blended learning* opportunities. Blended learning occurs when teachers use technology in the classroom to allow students to switch back and forth between learning from a live instructor and learning using digital-based media; this innovation is now the subject of experimentation and research.

Part IV circles back to the future of both education and the educational data movement in general. Piety points out that while many have criticized the use of data and other business reforms, few have offered concrete alternatives. Chapter 8 looks at problems with the educational data in terms of both quality and reliability. Despite years of experience in collecting data and the Data Quality Campaign discussed in Chapter 3, school data are known to be unreliable and inaccurate. Two of the reasons for these problems are cheating by both teachers and administrators, thought to be the effect of *Campbell's Law*—excessive reliance on a particular indicator causes that indicator to change in meaning. Several other problems are identified including the fact that even if the data are recorded correctly, there is imprecision in the tests themselves. Furthermore, virtually no diagnostic detail is recorded so it is difficult to determine precisely what the student did or did not know. Even if the same test is administered, the students have often been taught different content, resulting in a wide variation of scores. Finally, potential problems include incorrect recording of the teacher-student data link and the misleading outcomes that occur if a student has more than one teacher for a particular subject. Rather than recommending the abandonment of data projects, Piety suggests a new decision science that determines how "good" data must to be in order to be useful.

In the final chapter, Piety looks to the future of the educational data movement. Instead of making predictions about what will happen, he tells the reader what to watch for as we move forward, including what may be most important, the five social sectors: front-line practitioners; vendors and innovators; funders, federal,

state, and foundation; information providers; and the compliance/support boundary.

Front-line practitioners are split into two groups—traditional practitioners who come from schools of education, and reform practitioners who come through alternative certification programs and/or work in charter schools. In recent years, much has gone well for the reformers who have received larger donations from funders, while the traditional practitioners have found themselves objects of study and evaluation. While the focus has been on the reformers, the technical core of education is best understood by the traditional practitioners; without their input further reform efforts are likely to be difficult.

Vendors, whose core businesses of books and materials arguably benefit from the fragmented nature of our educational system, will now have to compete with innovators who develop their own materials and bring their own views of learning into the educational system. How the vendors adjust to this new competition will determine how much variety is available to districts nationwide.

Funders exist both within and outside government, but often their purposes are aligned. Private foundations can move quickly and can fund projects on a larger scale than most federal agencies. The relationship of these funders to the educational data movement will determine the direction of the movement in the future.

Information providers, such as states and the National Student Clearinghouse, have a wealth of information available for researchers. Continued development of relationships with other fields of science that have a longer history of data use will help researchers extract more useful data for the future.

The institutional boundaries between compliance and support are changing as the federal government becomes more directly involved in data management. States and districts have become more directly involved in the sharing of data. Rather than enforcing compliance, states are now becoming the repositories of student data.

Piety concludes the book with a description of the next generation of data systems. His framework, which he calls Educational Design Science, must meet five objectives:

1. *Focus on systemic processes across boundaries.* Good data systems must not only allow for data collection, but also make the data useful to others.
2. *Recognize and design for collecting often opaque data.* Systems and users must recognize that test data and other student data are, at best, an incomplete description of what a student knows or needs to learn. Designing systems to use multiple measures of performance is imperative.
3. *Use robust information structures.* Data are often over-simplified to the point of being less useful or even misleading. Rigid structures that assign students and teachers to specific classrooms look good from above but may not reflect the reality of the ways students and teachers interact. A system that is robust will more easily handle this ambiguity.
4. *Model temporality.* Until now, systems have focused on snapshots and disconnected timeframes. Systems must be able to show student and teacher trajectories over time in a compelling, useful way.
5. *Design flexible data systems that accommodate social structures.* In some schools, it is necessary to focus on student attendance, while in other schools it might be useful to focus on social services provided to students. Data systems must be flexible to meet the needs of the districts and schools.

Piety's approach to the analysis of the educational data movement is refreshing. Rather than assigning blame, or attempting to evaluate the worth of one policy over another, Piety suggests that, "the vast majority of those with different approaches to educational improvement share a common concern for children and for those who serve them" (p. xiii). By explaining the development of the educational data movement over the past several decades and the potential for the future, while recognizing its limitations, Piety provides a roadmap for school districts and administrators who are ready to become involved in data-driven decision-making. Given the overarching power of the high-stakes testing movement and its effect on teaching and learning, the balanced discussion provided by Philip J. Piety has the potential to contribute to a refined reflection on the ways valid data collection and analysis can improve educational opportunities for today's learners, including those who are underserved.

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E-books: Promising Possibilities

MICHELLE CARNEY AND STOREY MECOLI, *Journal of Education*

E-books are opening the door to a world of children's and young adult literature the likes of which we have never seen. A young child can help a peckish Big Bad Wolf blow down a straw house and aid a frantic pig to escape, while an older reader can learn 600 facts about dinosaurs or visit an historic site without ever stepping foot across the threshold. The possibilities are innovative, engaging, and promising.

In this review, we examine both fiction and informational sources that are likely to appeal to a wide variety of readers. While we typically rely on award-winning titles and authors to justify our review choices, the world of e-books, while growing, is still new enough to have only a few award panels. For this review, we have sought recommendations from well-regarded sources and selected titles that, in our view, reflect the qualities of outstanding print books enhanced by the interactive capabilities of digital resources. Some of the digital books and sources require access to tablets and touch screens, while others require only a computer.

In this issue of the *Journal* that focuses on technology, we note the promise of e-books and digital texts that was described by Larson (2010). In a description of her case study involving young students and digital readers, Larson commented on the possibilities of digital literacy. She noted that, "a plethora of tools and features allow the reader to physically interact with and manipulate the text, making the reading experience interactive and engaging" (p. 16). It is this potential for "interactive and engaging" literacy experiences that guided the selection of the resources we review here.

The Three Little Pigs

BY NOSY CROW DEVELOPERS, 2013 (LATEST UPDATE)

(Ages 4 and up)

Awards: Winner of Editor's Choice Award, Children's Technology Review Magazine; One of the Top Ten "Best Children's Books on the iPad," *The New York Times*; Five Stars from Common Sense Media

While some of the e-books featured in this review require more sophisticated and experienced reading ability to gain the most from the experience, this is not the case with Nosy Crow's active and engrossing version of *The Three Little Pigs*. Children as young as four will appreciate the colorful and lively animations, the familiar storyline, and the simpler dialogue and storytelling techniques in this reimagined classic. *The New York Times* named this version of *The Three Little Pigs* one of the top ten children's books for the iPad, and much of this acclaim may be attributed to the innovative and surprising interactions the reader is able to have with the text and the characters of the story.

Once opening *The Three Little Pigs* app, the reader has a choice of three options from which to choose. The reader may elect to have the text narrated while being able to explore and play with interactive components; the reader may choose to have the text read and the actions displayed automatically, like a movie; or the reader may choose to do everything independently, including the reading. What sets this text apart as being especially inviting to young readers is the built-in ways in which the reader is able to interact with the text. As the text is narrated, for example, the words being read are highlighted so that the reader may follow along. It is also worth noting that the characters' dialogue appears in a classic comic book bubble-style. Should the young child choose to read the words rather than listening to them, the app provides choice in determining the length of time the text will appear—short, medium, or long. Thus, *The Three Little Pigs* takes advantage of one of the greatest capabilities of e-books, choice that accommodates the individual reader.

From the first screen shot, the reader is introduced to the main characters, the three little pigs. One, tall and lanky, has wire-rimmed glasses and wears high-waisted pants and a sweater. Another, shorter pig wears flowers above her ears, a pink and orange jumper, and dances in place. The last little pig, his curly tail bobbing, sways back and forth in yellow overalls. Intermittently blinking blue dots let the reader know to click on the different pigs as they take turns giving instructions for the story. "Spread your fingers to zoom in," instructs the dancing pig, while the lanky one suggests, "Drag me to make me move." Once the reader gains a sense of how to "operate" the story, reading can begin.

The story unfolds in the way we expect. The three little pigs set out to make their way in the world, saying goodbye to their mother and father. Their mother advises them, "Goodbye my little ones. Be happy, but beware of the big bad wolf!" (n.p.). The reader can quickly figure out which pig fits which archetype. From the beginning, the lanky pig wonders, "Who will wash my socks?" (n.p.). The dancing pig bargains, "If you let me stay, I might even do the washing up" (n.p.). Only the smallest pig shows a spirit of excitement, proclaiming, "Let's go!" . . . "It will be an adventure!" (n.p.).

The story progresses with the first pig building his infamous house of straw ("This is easy. I hope I don't have hay fever" [n.p.]), the second building her house of sticks ("I'll have this ready soon" [n.p.]), and the third pig taking his time to build a house of bricks ("Oof! These bricks are really heavy!" [n.p.]) When the wolf shows

up, the reader knows what will happen. The first and second pigs watch as their houses are destroyed under the wolf's strenuous huffing and puffing, and are forced to take shelter with their more industrious brother. When the wolf fails to blow the third pig's house down and tries to force his way down the chimney, the littlest pig heats a pot of water over a fire, which the wolf drops into. The narrator tells the reader, "He burnt his bottom very badly and went howling down the road" (n.p.), and the reader can conclude that the wolf will do no further harm to the pigs.

What sets this version of *The Three Little Pigs* apart is the active role children can play. They may zoom in and out and scan the scenes for hidden details, such as a spider which can be found dangling somewhere in every page. They can make the pigs jump and move, often yelling "Whee!" as they do so. They can help the big bad wolf blow down the tenuously built houses. As the reader blows into the microphone of the iPad, the wolf follows suit, the houses shaking and trembling as the *reader* huffs and puffs. The animations of this creatively relayed classic are bright and colorful, with the characters often dancing or swaying in place as if anticipating the reader's touch. For the voice talent of the story, Nosy Crow has enlisted the services of British children to both read the text and give voice to the characters that brings them to life. In short, Nosy Crow's rendition of *The Three Little Pigs* is an engaging and collaborative experience for beginning readers.

The Fantastic Flying Books of Mr. Morris Lessmore

BY WILLIAM JOYCE AND BRANDON OLDENBURG

Published by Moonbot Studios LA, LLC, 2011
(Ages 6–12)

Awards: App of the Year, 2011: Apps Magazine; Best iPad App of 2011: ipadinsight.com

One of the most impressive and lauded e-books we discovered in our search is one that, ironically enough, celebrates the power of paperbound books and the joy they bring to readers. *The Fantastic Flying Books of Mr. Morris Lessmore* was first created and directed by William Joyce and Brandon Oldenburg as an animated short film, one that ultimately garnered an Academy Award. It was reimagined and adapted into an iPad app by Moonbot Studios, complete with text and interactive elements, and the result has been praised by Bob Tedeschi (2011) of *The New York Times* as simply "the best" (n.p.) and by Rebecca J. Rosen (2011) of *The Atlantic* as "the future of kids' ebooks" (n.p.). Rosen makes her argument by noting, "it will be clear that you're looking at something very special[the] product of a thoughtful, creative team of people dreaming big about the possibilities for children's literature in the age of the tablet" (n.p.). *Mr. Morris Lessmore* is an example of an e-book done right, one that does not sacrifice story for interactivity, but instead, creates a seamless celebration of quality literature and engaging interaction between reader and text.

Lessmore opens with a winningly old-fashioned scene. On a narrow porch sits Morris Lessmore, brown suit neatly pressed, tie straight, a straw boater perched on his head. He is seemingly engrossed in a novel, with other books stacked high all around him. At the bottom of the screen are the words, which are also narrated, a feature that can be turned on or off, as the reader prefers. The quality of the text and the appreciation of language and literacy are consistent exemplary features of this app.

Morris Lessmore loved words. He loved stories. He loved books. His life was a book of his own writing, one orderly page after another. He would open it every morning and write of his joys and sorrows, of all that he knew and everything that he hoped (n.p.).

After the text is read, translucent arrows urge the reader to swipe the screen, and then, out of nowhere, a powerful wind kicks up. The more the reader swipes, the more the wind blows, upending the stacked books and blowing helpless Morris all around. When the wind has settled, everything Morris knows has been blown away, "Even the words of his book" (n.p.). Onscreen, everything is now depicted in black and white. Morris becomes sad and aimless, wandering, until he comes upon a woman who is "being pulled along by a festive squadron of flying books" (n.p.). Feeling sorry for Morris, the mystery woman tosses him one of her favorite volumes. This footed book befriends Morris and leads him to an "extraordinary building," which turns out to be a magical library populated with many animated books eager and willing to share their stories. The world returns to color.

Morris' life with books is rich and full. He mends the damaged ones, tries to keep them in order, and lends them to other townspeople whose images turn to color as they read. "Everyone's story matters," Morris concludes at one point, "and the books agreed with him" (n.p.). The reader follows Morris through the rest of his life until his own story ends, and the book is contributed to the library where the tale of Morris's life with books can be read and enjoyed.

This e-book has the look and feel of a beautiful animated movie; Morris' changing facial expressions and the books' busy fluttering and flapping images are captivating. Its interactive elements are engaging and well thought out, seldom detracting from the story. For instance, the reader helps drag classics such as *A Christmas Carol*, *Treasure Island*, and *Frankenstein* into waiting villagers' hands. As they do so, the black and white images change to color with added features that portray the characters' personas. For example, when given *Alice in Wonderland*, a young boy grows rabbit ears and buckteeth, and proclaims, "I'm late! I'm late!"

This digital book gracefully blends the old with the new. Through advanced technology, readers can click on animated books that bellow out renowned lines from famous novels such as "It was the best of times, it was the worst of times" and "Quoth the raven, 'Nevermore.'" The result is an unexpected and winning combination. Additionally, readers have their own opportunities for creativity that include using the touchscreen to add pages to a book, spelling words with alphabet cereal, and playing the piano. All of this is done without sacrificing the story. The text is inviting and worthy storytelling and will appeal and speak to the reader with its insights into the world of books.

> Morris tried to keep the books in some order, but they always mixed themselves up. The tragedies needed to be cheered up and would visit with the comedies. The Encyclopedias, weary of facts, would relax with the comic books and fictions. All in all, it was an agreeable jumble. (n.p.)

With its careful attention to interactivity, engaging animation, and focus on story, this "poignant, potent ode to books" (Kirkus Review, 2011, n.p.) gives the reader a satisfying glimpse into what an e-book can and should be.

Alice for the iPad

STORY BY LEWIS CARROLL, IPAD APP BY ATOMIC ANTELOPE, 2010

(Ages 8 and up)

Alice for the iPad was launched in 2010, relatively early in the release of book apps. Its arrival was greeted with hearty enthusiasm, called "the cleverest iPad book yet" by Rosa Golijan of gizmodo.com and installed on more than 500,000 iPads worldwide (torontoreviewofbooks.com). For many of the fans of Lewis Carroll's classic tale about a curious young woman following a chronically late hare, this vibrant tribute to the book brings its whimsy to life in a new way.

Like many e-books, *Alice for the iPad* offers its reader many choices. Beginning with the colorful cover page, the reader can select either the abridged version of *Alice in Wonderland*—the "Bedtime Edition"—or the 249-page original version of the book. The text itself remains unchanged, and readers new or familiar will delight in Alice's exclamations of "Curiouser and curiouser!" (p. 21) and puzzle over the Hatter's riddle, "Why is a raven like a writing-desk?" (p. 123). Alice's fantastical journey is preserved and undiluted in this newest incarnation, from her run-ins with the Queen to her frustrating conversations with the Cheshire cat.

What is most inviting about this reimagined version of *Alice,* however, is the way the illustrations are brought vividly to life. Using the beautiful renditions originally created by Sir John Tenniel, the designers of the digital *Alice* have animated them in a way that does justice to both the original story and the illustrations. On the second page, a larger-than-life rendering of the March Hare's pocket watch is snagged on a large letter "S" and sways lazily back and forth in response to the reader's toggles. At the part of the story where Alice finds herself unable to fit through a too small passage into a colorful garden, the reader is able to glimpse just a sliver of the landscape that shifts in response to the touch. It is features such as these that allow the reader to experience Alice's wonderland as she does. Similarly, when Alice encounters the bottle decrying "DRINK ME," the reader can manipulate the drawing of Alice so that she stretches and grows before our eyes.

In discussing the way in which *Alice for the iPad* came about Chris Stevens, one of the creators, described his commitment to remaining true to this classic. He noted that Tenniel's use of woodblocks to create his illustrations provided prominent lines with which to work. Stevens noted, "Each page of the original Lewis Carroll book jumped out at me and elements seemed to beg to spring to life. It was supernatural really; this imperative to create movement in the pages" (torontoreviewofbooks.com). Because of this quality, Stevens suggested that *Alice in Wonderland*, in particular, lends itself well to an e-book adaptation.

In fact, *Alice for the iPad* might go a long way in persuading those wary of e-books of their value. The interactive components appear sporadically throughout the story. The reader's experience is enhanced, not diminished by these fantastical elements. Given the fact that *Alice in Wonderland* is a longtime standard of many middle school language arts curricula, it is not hard to imagine *Alice for the iPad* playing an engaging role in the classroom. This interactive, vivid, and entertaining update of *Alice in Wonderland* will engage many readers including those who are familiar with the classic tale and those discovering it for the very first time.

How Things Fly

BY THE SMITHSONIAN AIR AND SPACE MUSEUM ON-LINE EXHIBITS

(Ages 6–12)

Even in the twenty-first century, many young airline passengers marvel at their seemingly effortless rise into the sky and wonder how that enormous tube of metal stays aloft. Airplanes, and their interstellar cousin, the spacecraft, are among the great triumphs of the scientists who have been able to harness the power of nature. However, joining the birds in flight was not an overnight accomplishment. The earliest efforts of wax, wings, and wooden frames were no more successful for Icarus or Daedalus than they were for Leonardo da Vinci. It wasn't until the persistent efforts of the Wright brothers that the secrets of airborne travel were discovered.

The Smithsonian Air and Space Museum's interactive, online exhibition, *How Things Fly*, explains these secrets of flight in a comprehensive site appropriate for late elementary and middle school readers. The site can found by starting on the Smithsonian Air and Space home page (airandspace.si.edu), and selecting the educational tab from the main menu and then the online activities option from the drop down menu. Upon arrival, readers are greeted with a deceptively simple animation of a pilot as he tests his flying machine. With each failed trial off the cliff's edge, the reader is introduced to one of the four forces of flight; gravity, lift, drag, and thrust. This accessible animation provides novices just enough background information to continue to a more comprehensive exploration. From the animation, readers may select from two navigation options, learn more about the four forces of flight, or learn why humans were not built to fly.

The first option, *The Four Forces of Flight*, takes readers to a page featuring clear, concise definitions of each of the forces of flight. Following these definitions is a *Learn More* option that provides links to additional visual representations of the forces at work in airplanes and spacecraft. The second option offers examples of the earliest attempts at flight including the first patents for ornithopters.

The format of main topic and related subtopics is used throughout the site. First, the main category is presented with a brief description and a representative photograph, graphic, or animation.

The *Learn More* options follow this introduction, and the subtopics provide additional examples and information related to the main category through hyperlinked words that lead to definitions and explanations. For example, on the introduction page for the category "propulsion," the force of thrust is described as,

> Propulsion is the act of moving or pushing an object forward. The word is derived from two Latin words: *pro*, meaning before or forward, and *pellere*, meaning to drive. A propulsion system is an engine that produces thrust to push an object, such as an airplane or rocket, forward. (http://howthingsfly.si.edu/propulsion)

This consistency of format allows easy navigation around the site and provides a predictive format that will support younger or less-proficient readers. The pairing of the main topic with related subtopics also helps the reader to make critical connections between the many dimensions and applications of flight. The text is fairly considerate, using signal and transition words to emphasize description or cause and effect relationships. Key vocabulary terms are explained in multiple authentic contexts and with a variety of visual aids.

Other helpful navigational and concept development tools are found on the left side and right side of the web page. On the left side, readers can refer to the *Forces of Flight* graphic that indicates which forces are relevant to the topic on the displayed page. For example, when viewing the aerodynamics pages, the Forces of Flight indicator highlights *lift* and *drag* to emphasize the relevance of these forces to this topic. Additional features include "ask an explainer," sidebar fun facts, and suggestions for hands-on activities. One culminating hands-on activity, making your own paper airplane, is likely to be very popular. This option is more than a simple paper-folding demonstration, but rather, an exploration and application of all the flight concepts that have been presented. These options are well positioned on the page and enrich rather than distract the viewer from the important concepts.

Informational texts present unique challenges. The reader may begin with little prior knowledge on which to draw, encounter new concepts and vocabulary, grapple with abstract explanations, and encounter a range of text structures (Duke, Pearson, Strachan, & Billman, 2011). Teachers may find this site useful in helping students to understand the relationships between main ideas and details, and gain experience with one way to organize this information. The site is also a valuable addition to teaching an in-school science unit. Combining the text resources with the suggested hands-on activities is likely to provide high levels of engagement and motivation, particularly for those young people who have wondered about the dynamics of flight.

The Ultimate Dinopedia

BY DON LESSEM

Published by National Geographic Society

(Ages 6–12)

In not so distant times, a set of encyclopedia took up at least a shelf or two in the library. Now, much of the information these thick volumes contained is held within devices no larger than a notebook and is easily accessible through Internet queries. Such is the case with *The Ultimate Dinopedia* app published by National Geographic in collaboration with primary author, Don Lessem and consultant, Argentinean paleontologist, Dr. Rodolf Coia. Given these experts, readers can be assured of the authenticity and credibility of the information presented. In no description or illustration will the reader find humans defending themselves against the fierce Tyrannosaurus Rex; it would not be scientifically accurate.

This app provides a comprehensive resource for those captivated by the "power, diversity and mystery that is the dinosaur" (Coia, Author's page). Over 200 different dinosaurs are indexed, and there is much to learn about this diverse group of creatures. Indeed, dinosaurs have been found in climates as diverse as the frozen Arctic and the steamy jungles of South America. Some were larger by far than any of modern behemoth, and some were only the size of a robin. Paleontologists have even discovered that some dinosaurs lived in trees!

The apps home page provides a table of contents to guide the reader, classifying the dinosaurs first as either meat eaters or plant eaters. The home page also provides an icon that is present throughout the app to allow readers to easily move between sections. Selecting meat eaters brings the reader to the introductory page. Here, a richly detailed, scientifically accurate illustration by the app's artist, Franco Tempesta, brings these ancient beasts to life. The reader may pan the illustration, left and right, to see more. Beneath the illustration is a paragraph describing each item, creature, and detail represented. A swipe of a finger brings the reader to the encyclopedia section of the app, with its page after page of razor-toothed carnivores. Each page presents a member of the meat-eating family with a detailed illustration, its name in the upper-left corner with a pronunciation guide, and a navigation aid that allows readers to locate themselves within the app. The specific information about the dinosaur is presented within four categories: dino stats, the story (with optional audio reading of the text), fun facts, and picture information. These categories are consistent across all entries, providing a scaffold for young Internet navigators and struggling readers alike.

Other features include an index that lists each featured dinosaur with a small thumbnail picture and quick facts, interesting messages from both the author and the consulting paleontologist, and a glossary of terms. This glossary is fairly extensive and includes general science terms (theory, hypothesis), words associated with dinosaur discovery (migrate, excavate, fossil), and more specific terms used by paleontologists (Pangaea, Cretaceous period).

There are many features across this app that will assist the likely audience of elementary to middle school readers, particularly

those whose interest and background knowledge exceeds their reading abilities. The text on any given page is not extensive, but rather, presented in brief paragraphs. The language is appropriately complex, but the text is considerate in its use of transitions, embedded definitions of terms, and organization within common texts structures, such as classification and comparison. Within the descriptions, the reader may also develop emerging understanding of key scientific concepts of adaptation, habitat, and diet. These consistencies across the app provide a scaffold for both younger learners and those who still developing strategies for reading informational text.

A final feature, a dynamic audio presentation of selected text, provides equity of access and critical opportunities for struggling readers to increase word recognition and fluency. As teachers look to technologies and online media to support their instructional goals, high-quality, credible, and considerate apps and websites are needed. This *Ultimate Dinopedia* is likely to meet both the requirements of digital literacies and the principles of effective instruction.

Within These Walls

BY THE SMITHSONIAN NATIONAL MUSEUM OF AMERICAN HISTORY, BEHRING CENTER

(Ages 6–12)

AVAILABLE: http://amhistory.si.edu/house/

The relatively few students who have lived in older homes may have discovered bits and pieces of the lives of those who have occupied the home in the past; a page of aged newspaper, a wooden button, pencil marks on a door tracking the growth of a child. These occupants wish the walls could talk and tell the stories of these small discoveries. For the many who have not had this experience, *Within These Walls,* an interactive website by the Smithsonian Museum of American History, features a house in Ipswich Massachusetts, and "tells the stories of five families who lived in this house over 200 years and made history in their kitchens and parlors, through everyday choices and personal sacrifice" (Within These Walls homepage). Thanks to the preservation efforts of the citizens of Ipswich, the house located at 16 Elm Street was saved from demolition and moved to the Smithsonian Museum of American History in the mid-1960s. Although the reassembled house can be viewed at the Museum, this online exhibition offers a vicarious experience through pictures, texts, audio recordings, and cutaway diagrams.

The online journey begins at the home page that features a virtual map of the site including house clues, facts, and family stories. We learn that the Choates were the first family to live in the house, during the mid-1700s, at a time when America was still a colony of England. The Dodge family was next, occupying the house from 1777 to 1789, when the father, Abraham Dodge, fought in the Revolutionary War. Another resident of the address at that time was an African American man named Chance who was likely the Dodge's slave. From 1836 to 1865, the Caldwell family lived in the house, which was the site of meetings of the Ipswich Female Anti-Slavery Society organized by Mrs. Joshiah Caldwell.

Each family's page features descriptions of how the home was used, pictures of artifacts, an audio recording of a popular music selection of the time, and perhaps most intriguing, the primary documents that historians used to reconstruct the home's past. For example, evidence of Mrs. Caldwell's meetings was found in a newspaper clipping announcing the time and agenda for those interested in joining the group. Exploring the site brings history to life through the stories of real families interacting with the world as it was then. Tracing the time line of this one home, allows the reader to gain a sense of how history is made day by day, and the ways events large and small lead to new chapters in the story of America's past.

In addition to the stories of the families and facts about the house, the website provides many resources for both student and teacher. The reading list and links offer an annotated list of related informational and historical fiction books organized by grade level and time periods. The links include the sites from which some of the primary sources can be located. A downloadable research guide will intrigue budding historians who wish to practice their investigative skills. Teachers will appreciate the guide to using the website with students as well as related learning activities. *Within these Walls* is a unique website that offers readers an opportunity to explore history through the lives of those who lived in a particular place at a significant time in America's past.

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